BULLETIN OF THE SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY.

Vol. XI. Article IX. With a Map and Plates XXVII-LVIII. June, 1900.

THE GEOLOGY OF THE ALBUQUERQUE SHEET.[1]

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In pursuance of the plan outlined in the first volume of this series we present the first instalment of detailed geology of the territory. The area selected is that covered by the United States topographical "Albuquerque Sheet" surveyed in 1888. The topography upon this map is by R. H. Phillip and W. W. Davis of the United States topographical corps. We desire particularly to acknowledge the courtesy of the Director of the United States Geological Survey by whose permission the contours from the Albuquerque sheet have been used upon our map. Dr. Walcott also kindly enabled us to reproduce a number of the plates of Cretaceous fossils from the report of Mr. Stanton in Vol. 106 of the Bulletins of the Survey. For this and other courtesies at the hands of the survey we here desire to make acknowledgement, as well as to Mr. W. F. Cummins of the Texas survey, Professor Charles S. Prosser of the Ohio State University, the directors of the geological surveys of Illinois and of Minnesota, and especially to Messrs. H. O. Brooks and T. A. Bendrat, of the volunteer corps of our survey.

It is no disparagement of the excellent topographical work which has been done by the United States survey to admit that the present sheet, as one of the earliest to be completed, is not entirely reliable and may be employed with safety only in following the main topographical outlines. These inaccuracies, are, however, of less importance upon this sheet than in most parts of the

[1] Appearing simultaneously in the BULLETIN OF THE SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY, Vol. XI, and the BULLETIN OF THE UNIVERSITY OF NEW MEXICO, Vol. II.

territory because of the unusual simplicity of the geological features and the broad lines upon which they are expressed. There are no intricate problems of geological topography and the economic significance of slight deviations in contour is practically nil. It has been decided that the present sheets will be sufficient for our immediate purpose and that whenever it seems best to undertake a more accurate delineation of the topography it will be desirable to employ a larger scale for portions of the sheet.

The reason for the selection of this area lies primarily in the question of convenience. It would appear at first sight that it would be more profitable to undertake an area with more important economic interests and, as a matter of fact, most of the work of the survey has been directed in such lines. But Albuquerque, as the largest city of the territory and the point from which our survey proceeds, seems to have a prior claim. Moreover the very fact that in this region a large number of the important geological problems are expressed in lowest terms makes it important that this area should be mapped and studied before attempting the presentation of the more difficult areas adjoining. This sheet is in a sense the key to the neighboring mining areas and the knowledge of this terraine is the foundation on which the later reports will be built.

The sheet includes the area bounded by the meridians of 106° 30′ and 107° west and the parallels of 35° and 35° 30′ north, forming a rectangle of about 35 miles by 28.5 miles. This area of nearly a thousand square miles we have examined very minutely during the past three years but it must be confessed new facts of interest develop in each excursion. The broad outlines here laid down will require the work of years to fill in.

No high mountains occupy this area but the fringes of three systems cross its borders. On the east rises the abrupt western escarpment of the Sandias and from the northern part of this range a spur of schist projects beyond the border. The great fault line which gave rise to the Sandias lies wholly to the east of the sheet and the knob of schists may be supposed to be

either a secondary product of metamorphism or a portion of the uneroded cap of the granite forming the axis of the range. To the north-east the Cochiti range of augite-andesite (diabase) and trachitic tufa rises above the Tertiary plain here largely covered by a broad apron of recent basalt. Further west the granite ridge forming the Nacimiento range projects over the Jura-triassic and Cretaceous plains but the only influence of this range upon our sheet is visible in the fault and monocline which extends southward from its southern extremity and forms the eastern boundary of the Cretaceous in the Puerco valley.

The Albuquerque Mesa.

The central and largest portion of the sheet is formed by a large, low, triangular mesa bordered on the east by the valley of the Rio Grande, on the west by the Rio Puerco valley and on the north by the valley of the Jemes river. This mesa which faces Albuquerque on the west has been considered by Captain Dutton a part of the Zuñi plateau but the Captain seemed to have but the vaguest ideas of the geography of the country he so eloquently described in his monograph of the geology of the Mount Taylor region and supposed that the Rio Puerco flowed into the Rio Grande some miles above Albuquerque instead of at La Joya fifty miles south of it.[1] This mesa we may call the Albuquerque mesa and the basaltic peaks which form its most prominent feature the Albuquerque volcanoes. Opposite Albuquerque the mesa rises to 5700 feet or 750 feet above the river level. The dip of the underlying Tertiary strata is in the vicinity of 50 feet to the mile to the south-east so that the western rim of the mesa is three hundred feet higher than the eastern and at the northern portion the western bluffs attain a hight of about 6750 feet above the sea. The dip is greater in the northern portion of the mesa, doubtless as a result of the proximity of the axis of uplift south of the Nacimiento range.

[1] The passage reads as follows: "There are unfortunately within the limits of the region covered by the map given herewith two rivers named Puerco. One runs north-east of Mt. Taylor and empties into the Rio Grande a few miles north of Albuquerque." It may be added that the geological delineations are also incorrect in many particulars.

Three horizons can be recognized in the Tertiary composing this mesa, the uppermost being a layer of marl varying from ten to over twenty-five feet thick and found over all parts of the mesa where this level is reached. In some places, immediately beneath the thin surface loam or sand, what seems to be buffalo wallows have been excavated in it for the basis of which it was adapted by its impervious character. Thin layers of vegetable charcoal are occasionally seen in connection with the marl justifying the idea that they are of lacustrine origin. No study has so far been made of the organic remains but they will no doubt prove interesting. A curious question arises as to the relation of this supposed Tertiary marl to the so-called Albuquerque marl described in the American Geologist, Vol. XXII, page 34. The latter is evidently fluviatile in origin and it may be suggested that, inasmuch as there are fragments of the Tertiary marl scattered through the river materials, it is possible that the superficial marly layer is due to erosion and redisposition of the older formation. The diference in height of these marls is over 400 feet. The existence of a barrier in the Rio Grand valley below Albuquerque is suggested very evidently by the relations of the present to older river channels between Albuquerque and Socorro. These points are, however, reserved for another occasion. Beneath the marl is a sandy series which rarely is much indurated but is definitely stratified. The upper portion of this for perhaps seventy-five feet is of a reddish color, while the lower portions are lighter in color and contain less of gravel. The gravel is largely of chert and flint and may be traced to the Cretaceous while there are also granite fragments and andesite and trachyte pebbles. It is probable that the whole series from the infra-carboniferous granite and schist to the Cretaceous has been laid under contributions for the materials of the Tertiary sands but it is noticeable that in the vicinity of the red bed (Jura-triassic) these layers are prone to assume the red character of that formation and that in the neighborhood of the great tufa sheets of the Cochiti, for example, the materials are largely of a tufaceous and obsidian nature. Strata that may be the chronological equivalent in the vicinity of the bases

of the Scorro mountains are made up of trachyte and rhyolite fragments and the coarseness of the material diminishes with the distance from these sources. No estimate is now possible of the entire thickness of the Tertiary as seen in the exposures of this sheet. West of the mesa in the Rio Puerco valley we may secure sections like the following: White marl, 25 ft.; gray sands and gravel, 25 ft.; red sand, 40 ft.; whitish sand (unknown); hiatus; concretionary yellow sandstone, 25; flags and sand, 50; yellow flags, 5; gray sand and gravel, 65 ft.; coarse gravel. 12 ft.; pinkish crag, 40; crag with basalt (fault?) 25 ft.; crag, 50 ft.; lime sinter, 25; pinkish sand with flags, about 200 ft.; reddish brown concretionary sandstone, 35; white concretionary sand, 25; yellowish-pink sand, 75 ft.; white sandstone, unknown; fault, beneath which are sands and lignites of the upper Fox Hills group.

The portion of the mesa lying within the limits of our sheet is broken by only one intrusive, that which forms the Albuquerque volcanoes above mentioned. These basaltic cones or necks are prominent objects from the valley at Albuquerque from which they are distant less than eight miles. The five necks plainly evident in the series lie in a north and south line evidently along a fracture or line of weakness. It is not difficult to determine that this series is but a detached portion of a system extending along the entire Rio Grande valley. To the northward is the small Bernalillo volcano described in the American Geologist, Vol. XXII, page 40, Still beyond is the great San Phillipe lava sheet derived from the craters near the south end of the Cochiti range. Still further north vast flows occupy the Tertiary mesa south-west of Santa Fe and portions of these flows having poured into the narrow valley of the Rio Grand at White Rock cañon accummulated in terraces and superposed flows. At the north end of the cañon these Post-tertiary flows may be found penetrating and altering the tufa of the east side of the Cochiti range. North of Santa Clara begins an enormous flow of similar age and character covering thousands of square miles. Evidence of a post-tertiary dam and lake may be seen about San Ildefonso.

To the southward the series consists of a multitude of isolated peaks like those of Peralta, Los Lunas, Isleta, La Joya, Socorra, San Marcial, and others. Much time has been expended in the effort to determine the precise age of these basalt sheets and the results seem to be unambiguous. The fact that these lavas flow over the bases of the trachyte and rhoylite mountains and flows as at Socorro, and burst through and are interbedded in the tufa sheets as at the Cochiti district shows the basalt period to follow the trachyte period of eruptive activity. Direct superposition on the Tertiary sands in numerous places indicates their Post-tertiary age. Often the Tertiary strata are much altered and reddened by the contact, being baked and indurated in those places where the flow was thickest but less altered by the thinner portions of the sheets. The question as to the period that may have elapsed since these flows is more difficult of solution. We have so far failed to find an instance where the lava has flowed over the river deposits of supposed Pleistocene age. Wherever the river valley encroaches on the sheets of basalt the talus is smoothly removed for the most part. A very interesting instance is that of the Peralta volcano which is situated on the east side of the river opposite Los Lunas. Here the cone must at one time have been covered under the river deposits. No vestige remains of the lava sheet and the neck itself has been partly uncovered by later stages of the water. On the other hand, in those cases where the cones have burst through the Tertiary only they spread out in large sheets. It has been repeatedly stated that these lavas are of recent date and that they cover remains of human industry. So far as this portion of the territory is concerned this may be emphatically denied. Specimens of maize imbedded in what was presumed to be lava have been displayed in proof of the statement that man existed prior to these lavas. It is not denied that recent igneous flows have occurred in various parts of the West, but it seems very improbable that even the latest of these basalts could have been cotemporaneous with man in New Mexico. An analysis made by Mr. D. W. Johnson of the so-called lava containing corn proved it to be highly acid and to have a composi-

tion impossible for basalt or an ordinary slag. It was not till our attention was called to the nature of the clay resulting from the disintegration of the trachytic tufas in the Bland and Jemes district that the matter became plain. We heard much of an ancient smelter at the mouth of Pino cañon in the Cochiti range. After much search we found a portion of an arch composed of brick which were in some places so completely vitrified that the broken surface could be told from obsidian breccia in the adjacent range only upon careful inspection. Further search proved that the so-called prehistoric smelter is a portion of a brick kiln burned a few years ago to supply a stamp mill in the neighborhood and that the project had to be abandoned because of the vitrification of the brick. Still later we were able to duplicate the supposed lava with the corn imbedded near the village of San Isidro in the Jemez valley where either the Pueblo potter had the same misfortune or a fire in the granery not only charred the grain but fused the adobe and imbedded the grains therein. At any rate the artificial origin of the "lava" is perfectly plain.

The thickness of the lava flow from the Albuquerque volcano is rarely more than 25 feet and the inclination of the sheet is sharply toward the river and in one place toward the north end of the sheet it appears that there was a flow over the declivity formed by the bank of the then existing river, as a fragment of the flow occupies a lower level and is nearly buried in the sand of the flood plain. To the west the flow extended but a short distance from the craters. The northern border of the mesa is formed by the valley of the Jemez creek which is wholly excavated out of the Tertiary sands. The declivity is gradual and exhibits extensive and irregular erosion, while on the west side the mesa often presents a rather abrupt escarpment with fantastic battlements and bastions.

The mesa is entirely without water except such as is retained by the marl from recent rains but this suffices to sustain a good growth of gramma grass and accordingly affords grazing for herds of horses from the ranches in the river valleys. In those portions of the mesa where the marl has been eroded

the sand supports very scant vegetation and only about its margins a dwarf growth of cedar. The western slope is sparsely wooded affording fuel, some of which finds its way to Albuquerque.

The San Filipé Mesa.

The extreme north-eastern part of the sheet is occupied by a portion of the San Filipe mesa which fills the V-shaped area between the Rio Grande and the Jemes river. Nestled at the south-western margin is the picturesque Indian village of Santa Ana, while the similar village of San Filipe has a corresponding position at the south-eastern foot and the thriving town of Bernalillo lies east of the river opposite the point of the V. This mesa is really a part of the Albuquerque mesa and is similarly composed. It is simply severed from its ancient connection by Jemez river which we may surmise is a geological after-thought of recent origin, and capped by an independent lava sheet from cones lying to the north beyond the limits of our sheet. There is the appearance as of several superposed flows but so far as can be gathered these appearances are due, for the most part at least, to differences of level resulting from erosion prior to the flows, though there is evidence that there were waves of the lava which represent intermittent phases in the flow. The isolated vent which forms the Bernalillo volcano has been eviscerated by the subsequent erosion of the river and now exposes to view the neck and radiating dykes as well as the effects of metamorphism on the soft strata as explained and illustrated in Vol. I of this series.

The Sandia Mesa.

The Sandia Mesa occupies the south-eastern part of the sheet and rises from the Rio Grande flood plain which bounds it on the west to the base of the Sandia mountains. The inclination to the west may average about 75 to 100 feet to the mile. The slope is for the most part gradual and only slightly modified by arroyos of recent erosion. The mesa is treeless but supports a moderate growth of nutritious grass. The abrupt escarpments presented to the river face increase to the south-

ward being low hills at Bernalillo and bluffs perhaps seventy-five feet high at the mouth of the Tijeras arroyo. At the north the Tertiary sands emerge from under the Pleistocene gravels, as about Bernalillo, but to the south these exposures disappear. A shoulder of schist from the granitic series forming the base of the Sandia range is thrust into the mesa at its north-eastern corner and about this some Tertiary elments may be detected. The Pleistocene deposits have been described in some detail in the first volume.[1] In that paper the mistake was made of tentatively referring the stratified sands beneath the river deposits to the Cretaceous. It appears that these beds must be as late as Neocene Tertiary though as yet no positive identification can be made in the absence of distinctive fossils. The lowest member of the river series is what we called the Rio Grande loess and this horizontally stratified deposit of fine silt and sand occupies the valley of the river as far south at least as to near La Joya. It contains fragments of marl which may have been derived from the disintegration of the Tertiary marl deposits. It is impossible at present to decide as to the depth of the deposit but presumably it does not extend much below the water level in the river. A well driven at a point rather south of east and about four miles from the city is 370 feet deep. The lower 25 feet is in a water bearing zone the foundation of which is clay. Except at the top the material passed through was fine grained loess. This depth would correspond pretty well with the level of the river and as no bed of clay is known in the Tertiary it may be supposed that this well reaches the bottom of the Pleistocene series. Another well not more than two miles east of town is said to have a depth of 214 feet and to pass through the same loose materials. The loess is well seen in the bluff of recent erosion on the west bank of the river opposite the court house. Here some 75 feet are exposed in a single perpendicular wall. From the top of this bluff looking eastward there may be readily seen a layer of gravel about 25 feet thick which occu-

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[1] The Geology of the Environs of Albuquerque. American Geologist, July 1898. Reprinted in Bulletin Univ. New Mex., Vol. I.

pies a place in the loess exposure on the east side. This gravel may be found in some places on the west side on top of the bluff mentioned. This gravel bed evidently marks the period of high water and rapid erosion for it is deposited very irregularly in eroded areas of the loess. It may be conjectured that this was a period of melting of glacial ice to the northward. The materials of the gravel can be traced to the northern ranges and adjacent Tertiary and Cretaceous strata. The Albuquerque marl occupies the upper portion of the mesa over much of its surface and has many of the characters of the Tertiary marls of the Albuquerque mesa. It is however less regular and may be supposed to be composed of the material eroded from that formation during a period of comparative quiet. It may be traced southward along the river to the vicinity of La Joya.

The Sandia mesa receives a great deal of float from the mountains and accordingly, near the foot of the range there is an abrupt increase in the angle of inclination marking a talus portion. But even at a distance the coarser elements evidently derived from this source are more abundant at the surface than in the deepor portions. The eastern or major fault line forming the monocline of the Sandias runs at no great distance from the base of the mountain escarpment, as is shown by the fact that at a distance of from half a mile to a mile west of the immediate foot hills there appear portions of the formations above the Carboniferous either nearly horizontal or inclined gently to the east. One such fragment is composed of earthy limestone impregnated with calcite and lies about a mile north of the mouth of Tijeras cañon but does not appear upon the sheet. Another nearly west of the mouth of Hell cañon consists of red sandstone apparently of upper Permian or Jura-triassic age. The total throw of this single fault must have been at least 4000 feet.

The small spur of schists which projects into our sheet from the east should be considered in connection with the Sandia range of which it appears to be the off shoot. It is in reality cut off from the main range by the great Sandia fault and is to be regarded as a resultant of localized metamorphic activity incident to that great seismic disturbance. The material of this

spur with its numerous peaks is schist of various descriptions much seamed and veined with quartz. Somewhat extended search has failed to discover any true igneous rocks in the vicinity. The schists are largely hornblendic with chlorite alteration phases, but there are mica and hydro-mica phases and gneisses. The contact with the granite of the foot of the Sandias is not simple but there is a large area of slicken-siding and evidence of disturbance. Further north the fault cut off part of the Permo-carboniferous and superjacent strata and dropped them in various positions 4000 feet or more and the whole northern part of the range was shattered. The metamorphism was excessive. Essentially the same sequence of strata is found here as near the mouth of Coyote cañon further south and the coal measure limestone with its typical fossils is found near the base of the limestone series while the red beds follow in orderly succession as will be explained in connection with the San Pedro sheet. The fauna of the Permian is nearly obliterated by metamorphism, but traces remain. It would be expected that if the limestone originally contained lead there would be some segregation and along or near the contact of the lime and granite some mining operations have been carried on with indifferent results so far and there is little reason to expect much. The possibilities of copper would seem to be good theoretically but we have so far seen no evidence that the Jurassic or Permian has segregated copper within reach, though copper is reported. In the schists the numerous quartz veins have been opened here and there, chiefly in places where the decomposition of hornblende has produced a quantity of chlorite. In the absence of further information it would look as though the prospectors had mistaken chlorite for stain of copper or silver as often happens in this region. The veins are very white and clean and have what a miner calls a "hungry look" but very likely carry some traces of gold. The association is however distinctly unfavorable unless there are basic intrusives that eluded our search. Such intrusives occur in Hell cañon farther south. Tourmaline is the most common of the accessory minerals of the schists

and there are few interesting mineral accummulations even from a mineralogical point of view.

In all probability the Sandia fault was only one of a series of faults all with a dip to the east. It is probable, for example, that the axis of weakness indicated by the series of basaltic volcanoes marks the position of another fault. And the line separating the Tertiary from the Cretaceous upon the map is also another such line, as will be seen. A result of this system of monoclines is to leave a depressed area that may have formed a Tertiary sea or estuary occupying the entire width from the foot of the Sandia mountains to the west bank of the Rio Puerco. In the soft Tertiary strata of this sunken area the two rivers had no difficulty in excavating their Pleistocene and their present valleys.

The Rio Puerco Valley.

The valley of the Rio Puerco, after passing along the western foot of the Nacimiento range and skirting the west side of the Prieta mesa enters the sheet from the north-west in the midst of the Cretaceous area. It would appear that the lava-covered Prieta mesa was so far protected from erosion as to preserve a large series of strata which in the part of the valley covered by this sheet have suffered erosion and removal.

On the eastern border of Prieta mesa is another valley which receives numerous tributaries from the east forming deep and narrow gorges with precipitous sides cut in the hard sandstones of the Cretaceous.

Whether this east Prieta valley occupies a monocline must be left in doubt but a mile or more east of the eastern escapment bordering this valley the nearly horizontal strata are broken by a sharp monocline, one of a series of approximately north and south faults, found on the west side of the Albuquerque mesa. The break is sharp and in many places the resulting scenic effects are quite picturesque. The same fault continues southward along the Rio Puerco and as a result the strata about San Francisco, for example, dip to the south-west on the west side while on the east side of the river they dip to the south-east or east. The discordance seems to fade out to

the south or is rendered less apparent by the disappearance of the Cretaceous strata under the Tertiary on the east side of the stream. Above San Francisco the stream is flanked by Cretaceous hills leaving a rather narrow valley. The lowest horizon of the Cretaceous appears above the river level near the point where the valley enters the portion mapped.

THE CRETACEOUS AREA.

The entire portion of the sheet west of the Rio Puerco is composed of the fringe of the great Cretaceous and Jura-triassic series of the Mt. Taylor region. In the immediate vicinity of the Rio Puerco these shales and limestones dip gently away from the river to the south-west while in many places the exposures east of the river dip to the south-east and farther north the dip is to the north-east. The bottom of the Cretaceous is nowhere well exposed upon our sheet but the white and yellow sandstone lying above the vermilion division of the red beds appears to the east of the river near where it leaves the sheet to the north-west. No single exposure affords an opportunity to measure the thickness of the Cretaceous in our region but the sequence has been pretty well made out.

At the bottom is a well-defined bed of granular sandstone which is often quite pulverent though upon occasion it may become well indurated. The lower portion is white and attains a thickness of from 25 to 50 feet while the upper portion is more indurated and of a yellowish color. These two we shall include under the term "basal sandstone beds" and find them a useful bench-mark for the base of the Cretaceous.[1] The basal sandstone is followed by a series of dark, sometimes lignitic shales with a thickness of over forty feet which near the top contain bands of flags or sandstone impregnated with iron. Usually one of these layers at least is fossiliferous and has been termed the Gasteropod zone. Among the fossils so far identified in this bed are the following: Ostrea translucida, Exogyra

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[1] Farther to the westward this band reposes on the Dakota Sandstone or may perhaps be said to form a part of it.

laeviscula, E. Columbella, Liopistha concentrica, Comptonectes symmetricus, Baculites gracilis, Prionocylus woolgari.

About ten feet of flags follow the dark shales, which are followed by about 75 to 100 feet of yellowish gray shales passing upward into yellow sandstone about 75 feet thick. In the lower layers of sandstone or in the upper sandy part of the shale below it there are frequently developed large concretions often with a cement of iron. These concretions may be over four feet in diameter and often become conspicuous objects in the landscape. They have been found at so many places in the same place in the series that we have come to attach considerable importance to them as a means of identifying horizons. The concretions occur in the same relative place to the east of the Sandia mountains but there by reason of the great distortion and metamorphim, have been distorted and flattened. Several species has been recovered from the concretions though they are not usually fossiliferous. At the top of this Tres Hermanos sandstone is a rather constant band of pinkish sandstone which preserves a uniform thickness and weathers separately from the underlying massive beds. When freshly broken this sandstone is saccharoidal and nearly pure white. Its greater consistency and convenient and uniform thickness may make it available for quarrying at some future time.

Above the sandstone is a large series of very friable sandy shales which are everywhere so readily eroded as to leave their thickness somewhat obscure. They are broken by small layers of ferrugineous sandstone which are somewhat fossiliferous affording for the most part broken fragments. In the neighborhood of (sometimes above but oftener below) this series of sandstone layers is a very widely distributed and conspicuous zone of concretions characterized by the abundance of calcite crystals and the occurrence of a plentiful fauna. These calcareous and septaria concretions often abound in large ammonite shells and large species of Pinna and Baculites which weather out in a very good state of preservation. This zone has been found in the region of Cabezon mountain, south of the Nacimiento range and near Una de Gato east of the Sandia range always with

the same peculiar concretions and identical fauna. From this bed we have recognized a considerable series of fossils mentioned in the list given beyond. Above the cephalopod zone and the sandy shales overlying it is another large band of dark and yellow earthy shales at least 100 feet thick capped by massive sandstone perhaps 50 or 75 feet thick. This we have called the Punta de la Mesa sandstone because of its prominence at the place so called north of San Ignacio in the Rio Puerco valley.

The upper part of this series which is separated from the lower by a shaley portion has a varied fauna though the state of preservation is not all that could be desired in most cases. The Punta de la Mesa sandstone is undoubtedly of Fox Hills age though it has been very incompletely studied. Above it is an extensive series of mostly loose yellow sandstone with shaly phases which is not easily estimated. The section given on Plate XLVIII, No. 1 is from the east side of Prieta mesa north of our sheet but does not reach the top of the series. The fossils so far as preserved seem to be identical with those of the Punta de la Mesa, with others so far only found in the lignitic division above. We may estimate this series of Prieta sandstones at 1000 feet thick. It is well exposed in the low hills east of Punta de la Mesa on the east side of the Rio Puerco and here is followed by the upper or

The Lignitic Division.

This group is best seen east of the locality last named northeast of San Ignatio some three miles. The strike is south-west and the same series is thus exposed west of San Ignatio, the continuity of this area with the previously mentioned being broken by the intervening Puerco valley and flood plain. The series as exposed at the northern part of this area is as follows: The Prieta series occupying low hills east of the river for perhaps one quarter of a mile. These yellow sands and flags are greatly weathered and do not enable us to give an accurate section. They are followed by fifty feet or so of white sandstone with ferrugineous layers, 35 to 40 feet of lignite, 5 feet of white

sandstone, 35 to 50 feet of brown lignite, 30 to 40 feet of white sand with lignite bands, 75 feet of lignite with ferrugineous layers and in the latter numerous impressions of deciduous leaves and fruits, 10 feet of yellow sandstone, 25 feet of white sandstone, 2 feet of ferrugineous sandstone with many fossils, 25 feet of loose white sandstone and fossils, over 300 feet of white and ferrugineous sandstone with few remains. At this point is a fault along which lignite appears and also white sandstone as though overthrown, but farther study will be necessary to disentangle the confused relations. This we suppose to be the upper limit of the exposed cretaceous for the series following dipping to the south east is part of the Tertiary section given above.

The fault mentioned is that of the Isleta mesa monocline and may be traced for many miles north and south. A similar fault occurs about three miles west of San Ignatio. To the west of this the lower part of the series is visible and rises in the higher hills to the Punta de la Mesa sandstone but to the east of it the lignitic series occupies the entire area. The fauna of the sand above the lignite is abundantly illustrated beyond and seems to be closely allied to the Punta de la Mesa if not identical with it. It is a marine fauna and of Fox Hills age. Thus our first impression and the prevailing opinion of geologists who have seen these lignites that they are Laramie is overthrown. The leaves also, of which a large collection may be made, are not identifiable with familiar Laramie species. This same sequence is detected east of the Sandia mountains but we are prepared to find this series followed by fresh-water or brackish Laramie at that place when sufficient exploration is possible. Near the Isleta Mesa monocline fault is a bed of shark's teeth and similar remains are found east of the Sandias at the same horizon (near Una de Gato). Time does not permit a discussion of the flora and vertebrate fauna of this formation.

South-east of the lower end of Prieta mesa there are several isolated mesas which rise from the base-leveled valley like islands in a desert sea. One such in particular is a most conspicuous object in the large valley which opens into the Rio

Puerco valley at the point where that river enters the sheet. This remarkable mesa we have called in our notes the Island Mesa (Mesa Isleta). Passing northeastward from the Mesa Isleta one enters a picturesque confusion of eroded and dismantled bluffs of Cretaceous shale and sand. Some four miles distant is an excellent exposure of the contact with the Tertiary. The fault is very marked. The Cretaceous strata are tilted to an angle of about 45 degrees and the upper Cretaceous sandstone is brought to view with its abundant fauna. Above this is a yellowish sandstone and below it bands of lignite and gypsiferous shales. The monocline is very well marked and a part at least of the Tertiary strata seem to be involved in the up-lift. The red beds of the Tertiary bluffs on the west side of the Albuquerque mesa may be traced to the monocline without change of level but here they are abruptly titled. Under them and lying in contact with the inclined beds of the Cretaceous are beds of soft white sandstone with remains of vertebrates which we presume to be representatives of lower Tertiary strata than those elsewhere exposed to view. It is evident that the later stages at least of the movement causing the anticline took place after the Tertiary and this exposure therefore gives us no clue to the original relation between the Tertiary and the Cretaceous.

This monocline in some adjacent places exhibits less of the evidence of disturbance, the slip being abrupt with little alteration of level in the strata on either side. The Tertiary red sands are curiously modified in the neighborhood of this monocline for there are enormous areas covered with concretions of small and uniform size often in botryoidal masses. A few miles southwest of the south-west corner of the Zia reservation the lignites are exposed by the erosion of the Tertiary. The details of distribution of the surface exposures have not been studied nor have the economic conditions but the lignites are no doubt the same as those at the Isleta Mesa monocline farther south and there has been a considerable disturbance and dislocation which may be referred to the influence of the axis of the Nacimiento range.

The area immediately north of this sheet from the Zia reservation westward is very much broken by the erosion directed toward the Rio Salado. Deep defiles have been cut through the high escarpments looking toward the stream and much faulting has disturbed the uniformity of the exposures. Here it is possible to study the upper layers of the red series and the lower portion of the Cretaceous to good advantage in spite of the displacements referred to.

The proximity of the gypsum and salt to great lignite beds is of great commercial importance for it will hasten the time when these resources can be made available.

Resume of the Cretaceous.[1]

The American Cretaceous is essentially a transitional period; and, although its general paleontological features agree with those of Europe, its upper and lower limits cannot be as definitely defined. In Europe the Tertiary is nearly everywhere unconformable upon the Cretaceous, in America this lost interval is represented by the transition group known as the Laramie, while at the bottom of the series we have the transition group known as the Trinity.

The American Cretaceous period is usually divided into the Upper and Lower Cretaceous, these, however, do not correspond to the Upper and Lower Cretaceous of Europe, but are based entirely upon conditions found in this country. It was at first thought that the Lower Cretaceous was wholly wanting in America and that a great gap existed here; but recently it has been found in several widely separated localities; namely, in Texas (Comanche Grp.); in California (Shasta Grp.); in Canada (Kootanie Grp.); and on the Atlantic Border (Poomac Grp.).

The Cretaceous beds in England consist of

Upper Cretaceous	Chalk beds, with flint.

[1] The following notes were compiled for the present paper by Mr. H. O. Brooks.

Middle Cretaceous	Upper green sand and a few other beds.
Lower Cretaceous	Known collectively as "Lower Green sands" consisting of green sands and other arenaceous beds. (Dana, 312.)

In North America the beds are made up of green sand, and thick sand beds of other kinds; also beds of clays, shell beds, and in some of the states, especially Texas, limestone. The thickness of the beds in New Jersey is about 500 ft., in Alabama, 2000 ft., in the Upper Mo. Region, 2000 to 2500 ft., east of the Wahsatch, 9000 ft., while in Texas, the general thickness is about 800 ft. of nearly solid limestone.

The Cretaceous strata in America were evidently mostly deposited by shallow seas or along coasts, while much of the strata of Europe at this time were of deep sea origin, as is shown by her chalk formations.

Although comparatively speaking the Cretaceous rocks are not found very extensively in North America, yet, in several localities, they have important geological features and cover several large areas, which have been divided by White into the following regions:

Atlantic Border Region.
Gulf Border Region.
Texan Region.
North Mexican Region.
South Interior Region.
North Interior Region.
Pacific Border Region.

The South Interior Region and the North Interior Region are sometimes known as The Great Interior Region.

The Atlantic Border Region. The Atlantic Border Region includes portions of Pennsylvania, New Jersey, New York, Delaware, Maryland, Virginia, and South Carolina; also some islands off the coast of New England.

The formations are composed principally of gravels, clays, sands, and marls. Only in a few instances are they of sufficient hardness to furnish an exposure of any great value. The aggre-

gate thickness of all the strata of this region will not exceed 1000 ft., and even this thickness is not found in any one locality.

The Gulf Border Region. This region includes portions of Albama, Mississippi, Georgia, Louisana, Tennessee, and Kentucky. The geological features of the region are so similar to those of the former, that there is probably no Cretaceous stratum found in the one that does not also occur in the other. Although the rocks so closely resemble those of the Atlantic Border Region, they are on the whole of a harder character, and the aggregate thickness is greater, being about 2600 ft. We select the following section as being a typical one of this region :

Hilgard's Misssissippi Section.

Coffee Group.	Sands. Blue or reddish clays. Some beds of lignite.	300 to 400 ft.
Rotten Limestone Group.	Soft clays. Whitish limestones. Calcareous clays.	1200 ft.
Ripley Group.	Sandy limestones alternating with beds of dark marl.	300 to 350 ft.

The Texas Region. This region includes portions of Missouri, Arkansas, Louisiana, Indian Territory, and much the greater portion of Texas. In this region we have the whole Cretaceous Period from the Trinity formation to the Laramie formation. It is remarkable for its exposure of the Comanche series, which is probably the best representative of a great division of the Lower Cretaceous in North America. Its fossil fauna, such as Rudistae, Chamidae, and *Radiolites austinensis*, would seem to indicate that it was similar to both the Lower and Upper Cretaceous of Europe; but, from its position so far below the Dakota, it is placed in the North American Lower Cretaceous. The series consists of limestones, calcareous shales, and earthy calcareous material with stony concretions.

North Mexican Region. The geology of this region is very imperfectly known, but it is of great importance. Its boundaries lie mainly within Mexico, but it also includes portions of

southern New Mexico up to the mouth of the Pecos River and southern Arizona; also a little of western Texas. Charles A. White found the whole upper Cretaceous in this region from the Dakota to the Laramie, while nothing lower than the Comanchie has ever been found in the Lower Cretaceous. The most important exposure of the Comanchie formation has been found in Sierra San Carlos in the Mexican State of Chihuahua. Here Dr. Parry found an exposure of over 4000 ft. containing Comanchie fossils throughout, and consisting of bluish-gray compact limestones, comparatively pure, but, in part, argillaceous.

The Great Interior Area. The following table gives the Upper Missouri River Section of Meek and Hayden, also the modification of the same as adapted by C. A. White this region (See Rev. of the Cret. Form. of N. A.):

Upper Mo. River Section.	Modification of Same.
No. 5. Fox Hills Group.	Montana Formation.
No. 4. Ft. Pierre Group.	
No. 3. Niobrara Group.	Colorado Formation.
No. 2. Ft. Benton Group.	
No. 1. Dakota Group.	Dakota Formation.

The Laramie formation is not included under any of the above heads, but it is found in different localities throughout the whole of the Great Interior Region. It is probable that no true marine fauna occurs in this formation, but brackish water mollusks, such as Ostrea, Anomia, Corbula, Corbucula, and Neritina, and such fresh water forms as Unio, Anomia, etc., have been frequently found.

There has been some question as to whether this formation should be placed in the Cretaceous or the Tertiary. It is now, however, usually considered as a transitional period, but referred to the Cretaceous formations. (See White's "Review of the Cret. Formations of the N. Amer., p. 148.)

South Interior Region. This region comprises the whole of Colorado and portions of Kansas, Nebraska, Wyoming, Utah, Arizona, New Mexico, and north-western Texas. The strata, except a small portion in southern Kansas, are entirely of the

Upper Cretaceous, ranging from the Dakota to and including the Laramie.

Newberry estimates the total thickness of the strata in New Mexico to be about 3500 ft. and divides it into the Upper, Middle, and Lower Divisions, corresponding respectively to the Montana, Colorado, and Dakota formations given above. (See Macomb's Expl. Exped. Geol. Report, pp. 121, 122.)

In the Colorado and New Mexico Cretaceous strata it was found very difficult to discriminate between the shales of the Ft. Benton and those of the Ft. Pierre Groups. For this reason Mr. Clarence King proposed the new term Colorado Group "for the great clay group" of the Cretaceous in this region. But it has been found that it is just about as hard to apply the lithologic classification of the formations to this new group as it was to the older ones of Meek and Hayden. For this reason Dr. C. A. White in describing the Cretaceous formations of Colorado used the same nomenclature as Mr. King, but applied the term Colorado Group only to the Niobrara and Ft. Benton Groups, and placed the Ft. Pierre in the Fox Hills Group. This has been further improved upon by Mr. G. H. Eldridge, who adopted the same divisions as Dr. White, but changed the Fox Hills and Ft. Pierre Groups to that of the Montana Group, thus doing away with the confusion caused by using the term Fox Hills Group in two different senses. (See Eastern Colo. Section, below.)

The Pacific Border Region. This is a very long and narrow strip running along the coast from the southern boundary of California through Oregon and Washington into British Columbia. Both the Upper and Lower Cretaceous are represented. The following section is the one which was adopted by the California State Survey:

Upper Cretaceous	Tejon Group. Chico Group. Wallala Group.
Lower Cretaceous	Shasta Group.

The following section, Meek and Hayden's Upper Missouri River Section, we give in full. This section has long been con-

sidered by most geologists as the standard for the classification of the Upper Cretaceous formations in America:

UPPER MISSOURI SECTION.

(Meek and Hayden.)

			Estimated Thickness.
Upper Series.	Fox Hills Grp. Form. No. 5.	Gray, ferruginous and yellowish sandstone and arenaceous clays, containing Belemnitella bulbosa, Nautilus dekayi, Placenticerus placenta, Scaphites conradi, Baculites grandis, Auchiera americana, and a great number of other mulluscan fossils.	500 ft.
	Ft. Pierre Grp. Form. No. 4	Dark gray and bluish plastic clays, containing Nautilus, Placenticeus placenta, Baculites ovatus and compressus, Scaphites nodosus, Inoceramus sagenus. Middle zone nearly barren of fossils. Lower fossiliferous zone, containing Ammonites complexus, Baculates ovatus B. compressus, several species of Heteroceras, Inoceramus tenuilineatus, bones of Mososaurus, etc. Dark bed of very fine unctuous clay, containing much carbonaceous matter, with veins and seams of gypsum.	700 ft.
Lower Series.	Niobrara Div. Form. No. 3.	Lead gray calcareous marls, weathering to a yellowish or whitish chalky appearance above. Containing remains of fishes and Ostrea congesta, also several species of Textularia. Passing down into light yellowish, whitish limestone, containing numbers of several species of Inoceramus, as well as Ostrea congesta, fish scales, etc.	200 ft.
	Ft. Benton Grp. Form. No. 2.	Dark gray laminated clays, sometimes alternating near the top with seams of light colored limestone. Fossils, Inoceramus problematicus, I. tennicostatus, Ostrea congesta, Veniella mortoni, Prionocyclus woolgari, Scaphites warrenanus, Nautilus elegans, etc.	800 ft.
	Dakota Grp. Formation No. 1.	Yellowish, reddish and white sandstones, at places with alternations of various colored clays and seams of impure lignite. Fossils, Pharella? dakotensis, Trigonarca siouxensis, Cyrena arenarea, Margaretana nebrascensis, impressions of leaves, etc.	400 ft.

The following correlation tables are compiled from those given by C. A. White in his Review of the Cret. Formations of N. Amer., pp. 211-245, inclusive:

		Newberry's New Mex. Section	King's Section	Eastern Colorado Section	White's Colorado Section	North Interior General Section
Eocene	Y Z					
Upper Cretaceous	A B		Laramie Group	Denver Deposits and Laramie Formations	Laramie Group	Laramie Formation
	C D E F G H	Upper Cretaceous	Fox Hills Group	Montana Formation	Fox Hills Group	Montana Formation
	I J K L		Colorado Group			Belly River Formation
	M N O P Q R S T U V W	Middle Cretaceous		Colorado Formation	Colorado Group	Colorado Formation
	X Y Z	Lower Cretaceous	Dakota Group	Dakota Formation	Dakota Group	Dakota Formation
Lower Cretaceous	A B C D E F G H I J K L M N O P Q R S T U V W X Y Z					Kootanie Formation
Jurassic						

In his earlier work in New Mexico Professor J. J. Stevenson followed Professor Newberry in dividing the Cretaceous into upper, middle and lower divisions. In later papers (100 Meridian Surv. Vol. III, supplement) he united the Fort Benton, Niobrara and Fort Pierre groups under the name Colorado

Group but included the Fox Hills division with the Laramie, presumably because of the presence of important lignite beds in both groups.

Captain Dutton has given sections of the stratified rocks of the Zuñi plateau which would be of great value if they rested upon any adequate paleontological foundation. He obviously is in error in his identification of the Triassic, to which he ascribes a thickness of 1600 feet. At the base of the Cretaceous as here exposed he places the Dakota sandstone with a thickness of 250 feet. The Colorado shale series is said to measure 1200 feet and it is followed by 900 feet of lower Fox Hills and this in turn by 550 feet Upper Fox Hills and this by 800 feet of Laramie. Each of these divisions is separated from its neighbors by a bed of massive sandstone from 125 to 175 feet thick which is not reckoned in nor ascribed to any group. The total thickness of the Cretaceous, including the Laramie is made to foot up to 4125 feet.

Holmes had given in Hayden's report for 1876 a section of the San Juan valley in which from 500 to 800 feet of variegated marls and soft sandstone beneath the hard sandstone of the Dakota had been added to that group but it is obvious that these marls belong to our Vermilion beds or Jurassic group.

In Vol. IV, of the report of Surveys West of the 100 Meridian Professor Cope, in his introduction to the report on Mesozoic vertebrate fossils, offers a brief account of the stratigraphy of the region north of the Nacimiento range and, while it is difficult to follow his description and numerous inaccuracies appear in his estimates, it is yet interesting to see how this region impressed the great paleontologist in 1876.

The exploration was carried on from the valley of the Rio Grande to the region of the Gallinas and head waters of the Puerco via the Rio Chama. In the cañon of the Cangilon he encountered our red beds with the gypsum horizon apparently in the same relative position as in the Nacimiento region. Beneath it are the red and yellow sand and a thin layer of shale. The gypsum is in places 50 feet thick and is separated from the lowest Cretaceous by an interval of about 850 feet. This in-

terval is in some places filled by a mud-brown sandstone which Cope regards as the equivalent of Cretaceous No. 1 of Hayden's section at Colorado Springs.

Below the gypsum is a band of lemon yellow and still below this beds of vermilion red sand. It seems probable that Cope overlooked the upper two-thirds of the red bed series and that the 850 feet is greatly over-estimated, yet it must be admitted that there is still room for a very unusual development of the Dakota sandstone in this interval. The great variability in the thickness and frequent absence of this horizon is one of the remarkable peculiarities of the New Mexico Cretaceous. In the Nacimiento region adjoining that described by Cope the sandy series at the bottom of the Cretaceous is never as thick as 100 feet, and consists of yellowish and white sandstone of a massive but very pulverent nature while south of Mt. Taylor there comes in a bed of yellow sandstone of about 200 feet thickness below this horizon.

The gypsum is supposed to mark the top of the Jurassic, the thickness being given at 600 feet, while below it is the Triassic to which 1000 feet are ascribed, though the bottom was not seen. Cretaceous No. 2 with a thickness of 1500 feet follows the gypsum. It is composed of shales and contains the fossils of our "Gasteropod Beds" and probably also the "Cephalopod Shales" though it is not possible to determine what limits were selected in Cope's classification. To this division a thickness of 1500 feet is ascribed and it is followed by the sandy Cretaceous No. 3, also 1500 feet thick. This probably embraces our Punta de la Mesa sandstone and part of the Prieta Mesa section above it.

The thing that strikes one in reading Professor Cope's paper is the enormous exaggeration of all estimated heights. It is probable that the total thickness on the Mesozoic strata which he gives at 5600 feet must be halved. It has been our experience that an estimate made at a distance of the heights of exposures of these bright colored rocks is invariably too great. We have amused ourselves by making such estimates at a distance of five and then of one mile and even then found it

necessary to divide the distance when it was actually measured.

The lower beds of the red series Professor Cope refers to the Trias and reports that they are of fresh-water origin as they contain Unios and saurian remains. It may be doubted if the Unios actually came from the beds in question. If they did, a curious light may be thrown upon the occurrence of the copper so constantly found in this part of the series. The variegated beds of marl and sandstone are thus separated from the sands immediately beneath the anhydride, though there seems to be no special reason for such separation.

Professor Cope also mentions the fact that the Jurassic beds contain conglomerate lime strata and copper, all of which facts induce us to believe that he had actually in mind our lower red-bed division. It would then be convenient to use the gypsum horizon as the upper limit of the Triassic but this leaves us in doubt as to the lower limit and as to the place of the Permian.

Paleontology of the Cretaceous.

The purpose of the following list[1] is to serve as a running commentary on the plates accompanying this paper. It would be impossible at this stage of our study to present an adequate idea of the richness of the fauna of the upper Cretaceous and it would be presumptious to attempt even a full description of the collections already made without the means of broader comparison than we have at present. Nevertheless it is necessary to afford the student an opportunity to verify so far as possible the conclusions to which we have come and to supply the means of checking this part of the work. Several species which seem important as determinants of the several horizons have been collected and found undescribed so far as can be told at present. In a few cases new names have been proposed for these in order to facilitate reference though we should have preferred to defer the paleontological work till greater progress has been made.

For those whose chief interest in geology is economic it is

[1] The assistance of Mr. H. O. Brooks in the preparation of this paper requires special recognition.

hoped that the plates will prove useful for the determination of the rocks actually found in the field. Even though the engineer may lack the discriminating knowledge of the trained paleontologist he can in many cases satisfy himself of the position of a stratum by the simple inspection of the plates while others may be induced to carry the study farther by recourse to the published reports.

For the study of the upper Cretaceous as exposed in central New Mexico and Bernalillo county particularly the student will receive much assistance from "The Colorado Formation," by T. W. Stanton in Bulletin number 106, Meek's "Invertebrate Paleontology of the Upper Missouri," forming volume IX of Hayden's survey, and White's report in Vol. IV of the Survey West of the 100th Meridian.

MOLLUSCA.

Ostrea prudentia, White.

A form resembling White's figure is from the monocline north-east of Island Mesa and south-east of Prieta Mesa where it is associated with upper Fox Hills species.

Ostrea sannionensis, White.

This species occurs abundantly in the Punta de la Mesa sandstone and in some cases forms extensive layers in company with several other species. A form has been found with cruciate outline (see figure) due to the unusual development of the upper plicae but it is not thought necessary to institute a new name for it.

Ostrea lugubris, Conrad.

The typical form is found in the cephalopod shales in Rio Puerco valley. It would seem that the evidence is now complete that this species should include both O. blackii and O. belliplicata which have been found in the Eagle Ford group of Texas. We have specimens of the larger form from Una de Gato east of the Sandia mountains in the uppermost Fox Hills strata, which closely resemble White's figures of O. belliplicata.

Ostrea glabra, White.

Plate XXXIV, Figs. 1, 2.

Numerous well-preserved specimens of this Laramie species were found east of the Caballo mountains in connection with the coal beds and what seems to be a somewhat different form of the same species occurs at Cerrillos but the association was not sufficiently close to determine the age of the beds of coal.

Ostrea translucida, Meek and Hayden.

Plate XXXIV, Figs. 7, 8, 9 and 10.

Ostrea pellucida, Meek and Hayden.
Ostrea pellucida, White.
Not Ostrea pellucida, Defrance.

A very thin-shelled Ostrea is represented by numerous specimens which are probably from the "gasteropod zone" beneath the Tres Hermanos or large concretionary sandstone in the Rio Puerco valley. Our figures are from casts of the interior. It may prove that they indicate a new species. It would appear that the shell from Carthage figured on Plate XXXIII, Fig. 7 is of the same species. The plications are sometimes obsolescent but the general form is fairly constant.

Ostrea franklini, Coquand ?

Plate XXIX, Fig. 8.

Two casts of the interior from the sandstone of the monocline east of Island Mesa may belong to this or a similar species. Upper Fox Hills group.

Exogyra laeviscula, Roemer.

This species occurs very abundantly beneath the Tres Hermanos or large concretionary sandstone in the Rio Puerco valley and at Gallup with E. columbella.

Exogyra columbella, Meek.

Not uncommon in the "gasteropod zone" below the Tres Hermanos sandstone in the Rio Puerco valley and at Gallup.

Exogyra texana, Roemer.

Specimens apparently of this species occur in sands above the lignite in Rio Puerco valley.

Exogyra winchelli, White.

Fragments from the upper Fox Hills group near Una de Gato east of the Sandia range have been referred with some hesitation to this species.

Gryphaea vesicularis, Lam.

Plate XXX, Fig. 3.

This is a common species. Elaborate discussions by Gabb, Hill and other writers seem to have brought no agreement as to its synonomy. Gabb, in 1869 referred this form to G. pitcheri of Morton and identifies it with G. dilata var. tucumcarii of Marcou. Whitfield reported it in 1885 from the lower green sand marls of New Jersey though insufficient care on the part of collectors prevented him from determining the sequence of the varieties. The species probably has a large vertical range. There are large quantities of these shells exposed by the weathering of shales below the Punta de la Mesa sandstone east of Mount Taylor. This is the locality from which it was reported by White in 1875. Meek also received it from the Fort Pierre group of the Black Hills.

Inoceramus fragilis, Hayden and Meek.

Plate XXX, Fig. I and Fig. 2. Plate XXXIV, Figs. 3, 4 and 5.

Our specimens vary greatly in form and size but scarcely more than those figured by Stanton and White. Very common in the cephalopod shales and the Punta de la Mesa sandstone just above them. Figure 2 of Plate XXXV is from a cast of the interior and differs from the others in form but is associated with other casts which are more elongate and in other characters resemble this species. These are from shales east of the Caballo mountains.

Mactra formosa, Meek.

Plate XXXIII, Fig. 6.

Small specimens from Carthage are referred to this species which is said to occur in the higher portions of the Fox Hills group.

Mactra pulchella, sp. n.

Plate XXX, Fig. 5.

Shell small, oval-subtrigonal, compressed, somewhat longer than high, nearly equilateral, or with anterior side longer; basal margin a semi-elliptical curve, rather rapidly curving anteriorly and abruptly flexed to the posterior margin. Umbones approximated, incurved; anterior and posterior margins nearly straight and nearly at a right angle with each other; posterior umbonal slope obscurely angular; lunule and escutcheon well-marked.

The surface is ornamented by strongly raised concentric plications which are relatively more conspicuous on small shells. Length of large specimen, 1.25 inches. In general form this species resembles Mactra emmonsi, Meek. The generic characters are not distinct but there is apparently an external ligament.

From yellow sandstone above the Punta de la Mesa horizon, east of the Sandia mountains, near Una de Gato.

Mactra (?) *subquadrata*, sp. n.

Shell small-ovate-subquadrate, compressed, considerably longer than high; anterior side much shorter; basal outline a uniform semi-elliptical curve abruptly narrowed behind, broadly rounded in front; beaks small, approximated, distant more than one third the length of the shell from the anterior margin; shell thin, marked by fine concentric striae.

Length five-eighths of an inch, height one half an inch. The general form is much as in certain Carboniferous species of Edmondia. This very pretty shell occurs in the calcareous concretions of the cephalopod shales or in the "gasteropod zone."

Tellina (?) *perlata*, sp. n.

Plate XXXII, Fig. 5.

Shell transversely and broadly sub-ovate in outline, compressed; anterior margin more broadly rounded, posteriorly sub-acute. (The figure shows the posterior angle somewhat more acute than usual).

The beaks are slightly nearer the anterior margin, small. Hinge characters unknown, except that the casts show an impressed line anterior and posterior to the beak near the hinge. Shell thin, marked with numerous fine concentric lines. Length of large individual, 2.5 inches, height 2 inches. This appears to be a common species in the upper part of the Fox Hills group but we have thus far found no description of it. The name may be regarded as provisional.

Tapes cyrimeriformis, Stanton.

Plate XXXII, Figs. 6 and 7.

This beautiful shell is represented by two specimens, one from the valley east of Prieta mesa and the other from the cephalopod shales near San Francisco. The figure does not show the ligament which is probably broken. At first we supposed this to be a Callista.

Caryates veta, Whitfield.

Plate XXX, Figs. 6 and 7.

The specimens referred to this species are from septaria concretions in the cephalopod shales, Rio Puerco valley.

Tellina equilateralis, Meek.

This shell occurs in the higher layers of the Cretaceous above the lignite. Upper Fox Hills.

Idonearca (?) *depressa*, White.

Plate XXXV, Figs. 2-7.

From the same region in the Rio Puerco valley as that from which the original specimens came we have a variety of forms which have the hinge characters of Idonearca together

with the form of Trigonarca depressa. There are two varieties, one being shorter (figures 4 and 5) and the other more oblique. None of these agrees in form with the species of Idonearca figured by Meek and Hayden though the hinge structure agrees. The figure by Stanton for the hinge of T. obliqua does not apply to our forms though the casts are apparently identical with those figured by him on Plate XX, Figs. 5 and 5. There is abundant material from the horizon above the lignite beds in various parts of the territory but we are unable to decide that that there is more than one species.

Cardium pauperculum, Meek.

Plate XXXIII, Fig. 11.

What appears to be the species cited is abundant above the coal horizon at Carthage and in the Upper Fox Hills layers east of the Sandia mountains. We have also found it in the walls of the depression surrounding the Zuñi salt lake in western Socorro county. The figure illustrates a specimen in which the posterior slope is unusually angulate. Considerable variation occurs but the costae are simple and nearly uniform in all cases.

Cardium, sp. ?.

Plate XXXV, Fig. 1.

This fine large species we have so far failed to identify but not having access to all the descriptions we are unable to state whether it is new or not. It is not rare in the upper Fox Hills layers east of San Francisco in the Rio Puerco valley.

Pholadomya subventricosa, Meek and Hayden.

Plate XXX, Figs. 1 and 2.

Several specimens of this species were found in the septaria concretion of the cephalopod shales near San Francisco in the Rio Puerco valley.

Pinna petrina, White.

Plate XXXI, Fig. 5.

A large series of this striking species found near the original locality in the Rio Puerco valley and elsewhere in Bernalillo

county permits us to add a few details to the original description.

Our specimens are mostly in the form of casts of the interior derived from the septaria concretions of the so-called cephalopod zone which seems to lie near the base or perhaps below the base of the Fox Hills division.

The texture of the shell, where preserved, is lamellar and prismatic, the inner nacreous layer being frequently preserved. Strong lines of growth lie parallel to the anterior margin, which is more nearly straight than the posterior, but turn by rather an abrupt flexure, parallel to the curved free margin to an oblique union with the lateral carina.

The strongly curved posterior margin is joined abruptly by the free posterior lip, which is strongly arched rather than straight as represented by White. The striae of the posterior portion of the shell are parallel to the outline of the lip. The radiating striae are relatively inconspicuous and the beak is more abruptly acute than represented by White.

Legumen (?) *appressum*, Conrad.

Shell transversely elliptical, over twice as long as high; valves depressed, thin; shell narrowed anteriorly and acute at the anterior extremity; posterior end broader but sharply rounded at the middle of its height; hinge line long; ligament groove long and deep; surface marked with fine even concentric striae.

We at first considered this a new species but it may more probably be identical with the one quoted. Upper sandy layers above lignite in Rio Puerco valley.

Liopistha concentrica, Stanton.

Plate XXXIII, Fig. 5.

(Including L. elongata, Stanton.)

A number of specimens from the gasteropod zone in the Rio Puerco valley resemble L. concentrica closely but they are mingled with others of somewhat larger size that have the outline of L. elongata. These large ones, however, have the concentric markings as well developed as the smaller and some of

the smaller ones have nearly the form of L. elongata and have the surface preserved, showing it to be almost pustulate by reason of nodes developed upon the concentric striae. We doubt the possibility of separating these forms. The L. elongata form occurs also at Carthage (See Plate XXXIII, Fig. 5).

Camptonectes symmetricus, sp. n.

Shell small, not over three fourths of an inch in length; broadly oval in outline; hinge line imperfectly seen, apparently longer than half of the width of the shell; valves convex; cardinal slopes from the beak forming with each other nearly a right angle, straight; surface of valves marked by very fine, numerous, irregular, hair-like radiating striae which curve strongly upward toward the margin, and also by fine concentric striae.

In the gasteropod zone below the Tres Hermanos sandstone in the Rio Puerco valley. None of our specimens preserve the hinge characters or extremities of the ears but the character of the sculpture is similar to C. burlingtonensis.

Dosinia sp?

A cast from the same bed as the above is referred to Dosinia on the basis of a superficial resemblance to D. erecta, Whitfield.

GASTEROPODA.

Chemnitzia coalvillensis, Meek.

Plate XXVIII, Fig. 5.

A small species, our specimens of which are insufficiently preserved, may be referred here. From the upper Fox Hills layers above the lignite.

Chemnitzia sp.

A somewhat larger form than the above, which we cannot at present determine, is from the septaria concretions near San Francisco.

Gyrodes depressa, Meek.

Plate XXIX, Fig. 7a, b.

The figure is not exactly correct in the representation of the expansion of the lower part of the body whorl. Most spec-

imens agree well with the figures given by Stanton, particularly with the form with the more elevated spire. From the upper sandy layers above the lignite.

Turritella whitei, Stanton.

Plate XXVIII, Fig. 6.

The specimen figured is not well preserved but material discovered since the engraving was made show a shell of the size and characters of the Colorado variety of the species described by Stanton.

The revolving striae are unequal and nodose and there are not more than five large ones separated by small hair-like ridges.

Vanikoropsis tuomeyana, Meek and Hayden.

Plate XXIX, Fig. 4.

It is with considerable doubt that two specimens found as float in the Santa Fe marls west of Albuquerque mesa are referred to this species. Meek states that the aperture is wrongly figured on his plate. Our figure is somewhat restored and the spire is probably higher than the cast would indicate. The shell is very thick and beautifully sculptured. There seems to be no doubt that the specimens are from the upper layers of the Fox Hills above the lignite.

Priopsis bairdi, Meek and Hayden.

Plate XXXIV, Fig. 6.

We have but two specimens that can be referred to the present species, one being a cast of the interior and the other a nearly perfect shell, the surface of which, however, has been much injured by abrasion.

In form and, so far as can be seen, in surface characters it appears to resemble P. bairdi more closely than it does P. coloradoensis, Stanton. With the former it also agrees in coming from a high horizon associated with Fox Hills species. Sandstone above lignite, east of San Francisco. Also at Carthage in sandy shales above the coal.

Rostellites ambigua, Stanton.

Plate XXIX, Fig. 1.

A number of fragments seem to have the characters of the species quoted though they indicate a larger form than that described by Stanton. With that species it agrees in having two folds in the Columella. The surface is strongly ribbed and also has fainter revolving striae on the body whorl.

The species was originally described from the Pugnellus zone of Colorado, a horizon occupying a position above the Fort Benton series. Our form is abundant in the cephalopod shales at the foot of the Fox Hills division, or immediately below it.

Rostellites dalli, Stanton.

Plate XXIX, Figs. 3 and 5; Plate VII, Fig. 8.

This species is apparently common in the sandstone above the lignite east of San Francisco and at the monocline east of Island mesa. Fig. 3 is faulty in not showing the full height of the spire. Other and larger specimens are more characteristic though the revolving striae are more pronounced upon the upper part of the body whorl than in the type. The folds of the columella are nearly obsolete. The same species has also been found in the shales above the coal at Carthage.

Anchura (?) *fusiformis*, Meek.

Specimens from various places in the Rio Puerco valley, the original locality, show the revolving striae and general characters but are insufficient to verify the suspicion expressed by White that the generic reference is incorrect.

Volutomorpha (?) *nova-mexicana*, sp. n.

Plate XXIX, Fig. 2.

This beautiful species is abundant in the sandstones above the lignite in the upper Fox Hills at Una de Gato, east of the Sandias and at the monocline east of Island mesa. Not having seen the whole length of the columella the generic reference remains doubtful.

Shell of rather large size, elongate ovate in general form;

spire conical moderately elevated, consisting of five volutions; volutions convex, strongly lobed by the transverse grooves, about 16 of which are found on the second volution of a full-sized specimen; body volution nearly thrice the length of the spire; aperture long and rather narrow; columella, as far as seen, unmarked by folds; surface of body volution marked by strong transverse plicae which are strong near the upper aspect but increase by intercallation below so that they are there about of the same size as the revolving striae with which they produce a beautiful cancellated appearance. Near the upper (sutural) margin is a strong groove which separates a part of the whorl as a prominent band which continues to the spire. The upper volutions are more strongly lobed and on them the revolving striae are obsolescent. Shell thick; cast smooth. The species is more robust than any species of Volutomorpha known to us but the absence of the columella folds seems to prevent its reference to Volutiderma, or Voluta. Length about 3.5 inches.

Sigaretus textilis, Stanton.

Several specimens with about the size and form of this species and with the cancellated surface have been taken from the gasteropod zone east of San Francisco. The spire in some cases is proportionally larger than shown by Stanton but the individuals vary among themselves.

Harpa (?) *occidentalis*, sp. n.

Plate XXVIII, Fig. 4.

This beautiful shell cannot be definitely referred to any Cretaceous genus but seems to belong in the Harpidae. Body whorl enlarged; spire low, conical; aperture elongate, rather narrow, notched and curved below; inner lip smooth, covered with a callus; outer lip thickened. The surface is marked by broad, flattened, transverse ribs separated by narrower depressions with a square cross-section. The lower part of the body whorl has about five revolving grooves like those separating the transverse ribs. There is a shallow revolving groove near the suture. Length about three fourths of an inch. The figure is

from a specimen in which the spire has been partly abraded away but is otherwise apparently perfect. There are no teeth upon the inner lip. Upper layers of the Fox Hills near Una de Gato, east of the Sandia mountains.

CEPHALOPODA.

Baculties gracilis, Shumard ?

Our specimens agree with those doubtfully referred to B. ovatus by White and which have been identified as B. gracilis by Stanton. In the lowest fossiliferous horizon (gasteropod layer, in Rio Puerco valley).

Baculites asper, Morton ?

A large species with distant nodes as in B. asper occurs in sandstone above the lignite east of San Francisco.

Buchiceras swallovi, Shumard.

Plate XXVII, Figs. 1-4.

This beautiful species occurs in vast numbers in septaria concretions of the so-called cephalopod shales in the Rio Puerco valley where it is associated with Sphenodiscus lenticularis, Placenticeras placenta, Pholadomya subventricosa, and other lower Fox Hills species. The typical form as described by Shumard is abundant and is accompanied by a variety or possibly a distinct species characterized by the absence of nodes about the umbilicus, the greater lateral compression of the shell and the almost complete absence of the ribs. The paired dorsal nodes, though present, are inconspicuous. The sutural pattern is the same except that the serration of the lobes is less marked. Individuals with more prominent ribs and slight development of the umbilical nodes indicate the possibility of a transition to the type. The variety may be known as var. puercoensis. Plate XXVII, Figs. 3-4. It would seem that the two forms occur together wherever the species occurs.

Sphenodiscus lenticulare, Owen (sp).

Not common in the septaria concretions of the cephalopod zone, Rio Puerco.

Placenticeras placenta, Dekay.

This delicate species is also from the septaria concretions in the Rio Puerco valley.

Placenticeras costata, sp. n.

Plate XXVIII, Figs. 2-3.

Shell lenticular, compressed, of moderate size; umbilicus very small; volutions deeply embracing, widest a little distance from the umbilicus; dorsum flat or slightly channeled, crossed by a continuation of the nodes; surface marked by numerous irregular subtriangular and curved ribs, the larger ones extending from the dorsum to the umbilicus and separated by one or more short oblique ribs originating on the dorsum where they give rise to small elongate nodes; aperture apparently narrowly cordate, flaring on either side of the volution embraced by it; septa moderately distant, siphonal lobe wider than long, with lateral divaricating branches; first lateral lobe small with two lateral projections and trifid terminal portion; first lateral sinus much broader than the lobe, composed of four portions, the median one five-digitate at the end and with a spur at either side, two small branches on the peripheral side and a small trifid branch on the umbilical side; second lateral sinus broken by two small spurs; third lateral lobe with five terminal and two lateral projections; remainder of sutural pattern unseen. This shell resembles in many respects Placenticeras placenta, from which it differs not only in sutural pattern but also by the presence of well-defined ribs. In this respect it resembles the Mexican form reported by Gabb, Pal. Cal., Vol. II, Fig. 258, which seems not to be Ammonites piedernalis, von Buch. Diameter of only specimen seen 95 mm. maximum thickness 21 mm. In septaria concretions of the Rio Puerco valley associated with Buchiceras swallovi, Placenticeras placenta, etc.

Scaphites nodosus, Meek and Hayden.

Our material is all of too fragmental a character to admit of more than doubtful identification, but indicates a rather large species with the nodose surface characteristic of the species

quoted. East of Sandia mountains, at San Antonio in a horizon above the Cephalopod shales.

Scaphites sp ?

Associated with the above are fragments of a smaller shell like S. nicolletti but agreeing with S. nodosus in the presence of node-like elevations near the umbilicus.

Prionocyclus woolgari, Mantell.

Plate XXVIII, Fig. 1.

This species occurs apparently in the Tres Hermanos sandstone above the Gasteropod zone in Rio Puerco valley. This seems to be about the equivalent of the Fort Benton division.

Vertebrata.

In the sandy layers above the lignite in the Rio Puerco and also east of the Sandias at the same horizon are numerous teeth of sharks, among them specimens of Otodus as figured by Cope on Plate XXII of his Extinct Vertebrata of New Mexico. Part of the carapace of a turtle was found in the same beds.

Plantae.

Numerous plant remains are found in the shales accompanying the lignite in the series above the Punta de la Mesa sandstone, but it does not seem desirable to attempt to discuss them at present. They do not seem to be of the Laramie flora and there are numerous marine fossils in the sandstone above the lignite belonging to the Fox Hills fauna and closely resembling the fauna from the Punta de la Mesa itself.

The Permian.

Review of the Literature.

D. W. Johnson.

Before referring to the work done in the Permian of New Mexico it may be well to review the literature hitherto published on the Permian of various localities at home and abroad. Probably no geologic age has claimed more attention and given

rise to more bitter controversies in recent years than has the Permian. The fact that the Permian is essentially a transition period accounts for much of this lack of unanimity of opinion, while the scarcity of fossil remains increases the difficulty of accurate correlations. Some geologists have sought to escape these difficulties by abandoning the Permian system altogether, merging it with the Carboniferous. But the fine development of this system in various localities, and especially in the Texas beds in this country, shows that the Permian is a great and widely distributed system, even though the scarcity of palaeontological evidence often renders it difficult of identification.

Palaeontologically the Permian is most closely related to the Palaeozoic rocks, and most geologists have followed Murchison in regarding it as belonging to the Palaeozoic era. The fact that Marcou and others have classed it as Mesozoic has been explained as the result of a mistaken idea that Murchison included in his Permian a large part of the Triassic.[1]

Stratigraphically the Permian is more closely allied to the Carboniferous in some localities, and to the Triassic in others. In some portions of the west it would appear that there had been continuous sedimentation from the Carboniferous through the Permian into the Triassic. Without entering further into the discussion of the correlation of the Permian with the Palaeozoic or Mesozoic, we prefer to follow the lead of those who place it in the former era.

Permian in Russia and India.

In 1841 Sir Roderick Murchison carried on extensive studies of the rocks of Russia, and proposed the establishment of the Permian system, named for the ancient kingdom of Perm, to include the later Palaeozoic rocks. This system is well defined and extensively studied in Europe. In India, Waagen has made an extensive study of the Permian, and described it more elaborately than any other writer. He divides the system into three groups,—Permo-Carboniferous, Rothliegendes and Magnesian

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[1] Notes on the Geology of Northwestern Texas, W. F. Cummins, 4th Ann. Rep. Geol. Surv. of Texas, p. 213.

Limestone, placing the red and gray sandstones and shales of Nebraska City under the second, and the Wichita division (Cummins) of Texas at the base of the third.

United States.

In the United States the Permian apparently occupies a place in the geological chronology not represented by any strata in Europe. Hence all attempts to correlate the Permian of this country with that of Europe have proven futile.[1] Permian was first reported from this country by Jules Marcou in 1853, west of Zuñi in Arizona, and in Indian Territory.

In *West Virginia* and *Pennsylvania* over 1000 feet of the Upper Barren Measures (1044 feet in Monongalia county, West Virginia) have been referred to the Permian upon evidence of the flora. The beds are there known as the Dunkard Creek Series, and are conformable with the lower series.[2] The Wasatch Section, *Utah*, constructed by the Geological Survey of the 40th Parallel, shows 30,000 feet of conformable strata of which the upper 650 feet, characterized by clays, marls and limstones, have been referred to the Permian.[3] The Kanab Section, *Arizona*, constructed by Walcott, shows 710 feet of Upper Permian characterized by gypsiferous and sandy shales and marls, with impure shaley limstone at the base. Also 145 feet of Lower Permian, characterized by more massive limestones.[4] Permian has also been studied in Illinois, Indiana, Nebraska, Missouri and Indian Territory. Also in Nova Scotia, New Brunswick and Prince Edward's Island. But in Kansas and Texas the work done in the Permian is so extensive and important as to deserve a more detailed account.

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[1] 4th Ann. Rep. Geol. Surv. of Texas, p. 220.

[2] Bull 65, U. S. Geol. Surv., Chap. II, p. 20. Also 2nd Geol. Surv. of Penn. Report P. P., Chap. III, pp. 105, 120.

[3] 3rd Ann. Rep. U. S. Geol. Surv. '81-'82.

[4] 3rd Ann. Rep. U. S. Geol. Surv., '81-'82.

Permian in Kansas.

Professor Prosser in his "Classification of the Upper Palaeozoic Rocks of Central Kansas"[1] has reviewed the work of Swallow and Hawn, Meek and Hayden, Newberry and others, the earlier writers on the Permian of Kansas. Shumard, Hitchcock and Marcou described rocks in the Canadian-Red River district which have been correlated with the Cimarron Series of Kansas, Marcou referring them to the Permian and Triassic, and Shumard and Hitchcock to the Carboniferous.[2] Beds still higher in the series were studied by Prof. St. John in 1886, and referred doubtfully to the Triassic. The later excellent reports on the Permian of Kansas by F. W. Cragin and C. S. Prosser are referred to more in detail below.

Professor Cragin gives the following:

"*Classification of the Rocks of the Permian System in Kansas.*"

II. Cimarron Series, 1100 to 1250 feet.

Divisions.	Formations.
Kiger, 250 feet.	Big Basin Sandstone, 12 feet or less. Hackberry Shales, 15-20 feet. Day Creek Dolomite, 1-5 feet. Red Bluff Standstones, 175-200 feet. Dog Creek Shales, 30 feet.
Salt Forks, 900-1000 feet.	Cave Creek Gypsum, 50 feet. Flowerpot Shales, 150 feet. Cedar Hills Sandstones, 50 to 75 feet. Salt Plain Measures, 155 feet or more Harper Sandstones, 650 feet.
	I. Big Blue Series, 900 to 1100 feet.
Sumner, 550-800 feet.	Wellington Shales, 250-450 feet. Geuda Salt Measures, 300-400 feet.
Flint Hills, 400 feet.	Chase Limestones (Prosser), 265 feet. Neosho Shales (Prosser), 130 feet.

The following generalized section is compiled from Professor Cragin's article in Vol. VI, Colorado College Studies:

[1] Jour. Geol. Vol. III, Nos. 6 and 7, 1895.

[2] Colorado College Studies, Vol. VI, p. 1.

Cretaceous --

Cimarron Series.	Kiger Division	Big Basin Sands	Sandstone, red and greyish white.
		Hackberry Shales	Maroon colored shales.
		Day Creek Dolomite	Dolomite.
		Red Bluff Sands	Light red sands and shales.
		Dog Creek Shales	Dull red argillaceous shales with 2 ledges of unevenly lithified dolomite in upper part.
	Salt Fork Division	Cave Creek Gypsum	Gypsum (Medicine Lodge). Red clay shale. Gypsum.
		Flowerpot Shales	Gypsiferous clays, variegated colors, red prevailing.
		Cedar Hills Sands	Massive concretionary, fine grained, bright red sandstones.
		Salt Plains	Red shales, some sandstones, with saline impregnations.
		Harper Sands	Brownish red argillaceous and arenaceous sands and shales. Copper carbonate occurs.
Big Blue Series.	Sumner Division	Wellington Shales	Bluish grey shales, with beds of impure lime, gypsum and dolomite.
		Geuda Salt Measures	Shales of variegated colors, also gypsum, rock salt, gypsiferous shales, thin lime beds.
	Flint Hills Division	Chase	Some shales, massive lime, including three zones of flinty lime.
		Neosho	Shales and thin bedded, often marly, lime.
			A few feet lower is the Fusulina lime of Swallow.

As will be seen, Professor Cragin places all of the Red Beds, or Cimarron Series of Kansas in the Permian, and recognizes no Jura-Trias. For a detailed account of the former series, see Professor Cragin's paper on "The Permian System in Kansas," Colorado College Studies, Vol. VI, 1896. Professor Prosser, in a series of excellent papers on the subject, gives the following:

"*Classification of the Upper Palaeozoic Rocks of Kansas.*"

Cretaceous ---

		Division.	
Permian.	Cimarron Series 1150-1400 feet	Kiger	Sands, shales, dolomite ; red color prevailing.
		Cave Creek Gypsum	Gypsum and shales.
		Salt Fork	Shales and sands, red color prevailing.
		Wellington 200-450 feet	Shales.
		Marion	Colored shales and marls. Marls and shales with gypsum. Thin buff lime and shales.
	Permo-Carb.	Chase 265 feet.	Massive limes and flint, beds of variegated shales. Three flint horizons.
		Neosho 130 feet	Grey lime and variegated shales.
Upper Coal Measures.		Cottonwood 20 feet	Yellowish calcareous shales. Cottonwood, Alma or Manhattan stone, a massive yellowish to light grey lime.
		Wabaunsee 575 feet	Massive lime, calcareous and argillaceous and arenaceous shales, occasional thin stratum of coal.

. . . . . .

Missouri formation (?) of Keyes.

The Geuda Salt Measures of Cragin are correlated with the Marion of Prosser. Professor Prosser objected to the ten divisions of the Cimarron Series as made by Cragin, on the ground that the differences between the numerous formations were largely local, and could not be recognized over any considerable extent of territory.[1] He regarded the two *divisions* of Cragin as *formations*, and assumed the Cave Creek Gypsum as the dividing line between the two. The Big Basin Sandstone, the uppermost formation of Cragin's Permian, is correlated by Prosser with the Comanche.[2] He follows Cragin in referring all the Red Beds to the Permian.

The Cretaceous and Tertiary in Kansas are unconformable on the Red Beds, while in some places the whole Cimarron

[1] Kansas Geol. Surv., Vol. II.

[2] Kansas Geol. Surv., Vol. II.

Series is lacking and the Dakota sandstone is deposited unconformably on the lower formations of the above classifications. The line between the Upper Coal Measures and the Permian or Permo-Carboniferous is arbitrarily drawn, and is based wholly on palaeontological evidence, the strata being conformable.

Concerning the age of the Cimarron Series of Kansas much has been written. It has been referred in turn to Permian, Permo-Trias, Jura-Trias, Triassic, and even to Cretaceous. Prof. Cragin correlated the Kansas Cimarron Series with the Texas Permian, and Prof. Prosser accepted this correlation, provisionally. In a more recent paper Dr. Williston says, "That these red beds are not contemporaneous with the Texas Permian would seem assured, and I feel yet more confident that they are what they were first considered to be, of Triassic age." Prof. Grimsley regards the Red Beds as marking the transition from the Permian to the Cretaceous. Mr. Vaughan, of the U. S. Geological Survey, studying the Upper Palaeozoic and Cretaceous of Oklahoma and Indian Territories and Southern Kansas, spoke of the Red Beds as Permo-Trias. In several localities fossils have recently been found in the Red Beds, and it may not be long before the question as to the age of this series will be definitely settled.

Permian in Texas.

The finest development of the Permian system of this country is found in Texas. As defined by Professor W. F. Cummins it includes "all the Red Beds in Texas which lie between the upper part of the Albany Beds of the Coal Measures and the Dockum Beds, or the lower part of the Triassic as recognized here." (In a more recent paper Prof. Cummins states that the Albany Beds have proved to be but another phase of the Wichita Beds, or lower Permian. The dividing line between the Permian and Coal Measures then becomes the contact of the Cisco division with the overlying Wichita—or Albany—Beds.) The rocks of the series in Texas are similar to those of the Kansas Permian, comprising limestones, sandstones, shales, red and blue clays, and gypsum beds. As in Kansas,

there is a slight difference in dip between the older and later strata in the same series, while the Permian is conformable with the Coal Measures below, and unconformable with the Triassic above. The Permian in Texas attains a thickness of at least five thousand feet.

Permian was first reported in Texas by Jules Marcou in 1853-54.[1] Dr. William De Ryee (1868), Prof. Jacob Boll (1880), Prof. C. G. Broadhead, Prof. E. D. Cope, and Dr. C. A. White referred the Texas beds to the Permian, while Prof. Edward Hitchcock in a report based on the notes of Capt. Marcy's exploration of the Red River in 1852 referred them to the Cretaceous.[2]

Prof. Cummins divides the Permian of Texas into three divisions, under the names of Wichita Beds, Clear Fork Beds, and Double Mountain Beds. The Wichita Beds (1800 feet) are composed of sandstones, clay beds and a peculiar conglomerate, while the portion formerly referred to the Coal Measures under the name of Albany Beds, consists largely of limestones and clays. The Clear Fork Beds (1975 feet) are composed of limestones, clay and shale beds, and sandstones, and the Double Mountain Beds (2075 feet) of sandstones, limestones, sandy shales, red and bluish clays, and thick beds of gypsum.

The Shinarump Conglomerate of Major Powell, which Mr. C. D. Walcott places as the divisional line between the Permian and Triassic, seems to be a very constant horizon, and is reported by Dutton from the Grand Cañon district. Prof. Cummins adopts this horizon as the line between the Permian and Triassic of north-western Texas.

Fossils have been found in all three divisions of the Red Beds of Texas, Triassic types occurring in the lower beds along with Coal Measure and Permian forms, while characteristic Permian forms have been found within 300 feet of the top of the Double Mountain Beds. No systematic attempt has been made to correlate these beds with strata in other localities, although

[1] Texas Geol. Surv., 2nd Ann. Rep. p. 398.

[2] Texas Geol. Surv., 2nd Ann. Rep. p. 400.

Prof. Cummins in a paper read before the Texas Academy of Science, June 15, 1897, says, "The *Phacoceras dumblei*, Hyatt, has been found only along a very narrow horizon in the Texas Permian. . . This fact will assist materially in correlating the Texas and Kansas beds, as that fossil has been reported only from one locality in the Kansas area, where it is associated with the same fossils as in Texas. It is quite certain that the Fort Riley horizon is the same as the Wichita division of Texas, and is at the very top of the division. With one horizon definitely established, it will be easy enough to correlate the other parts of the formation in the two areas."

An extended discussion of the Red Series is not necessary in this place as we have recently printed extended descriptions of the surface geology of the Red Series as seen in the region of the white sands in Otero county (current volume of the Journal of Geology) and also an article covering the present region in the American Geologist. From these it will be gathered that the three-fold division of the series is sustained and that on paleontological evidence the lower division (red beds proper) may be assigned to the Permian. The gypsum is often the upper limit of these beds though evidence is lacking to prove that it is constant in position where present. The chocolate division we assign to the Triassic solely on stratigraphical grounds and similarly assign the upper loose marls and sands (vermilion beds) to the Jurassic. The correlated sections (Plate XLVIII) will illustrate the sequence. On the Albuquerque sheet very limited portions of the Red Series appear. The vermilion beds occur in the valleys at north-western portion beneath the Cretaceous. Everywhere the saline and gypsiferous character is preserved and the region south and west of the Jemes mountains is a good illustration of the lurid colors and desolate landscape of the saline areas. Along the fault line west of the north-west corner of the Albuquerque mesa a low series of hills lying east of the fault line and consisting of red and white sandstone tilted sharply to the east represents a metamorphic portion of the Red Series but the sequence cannot be made out with certainty.

The Fauna of the Pleistocene.

Little has been done in the collection of material for the study of the fossil remains of the pleistocene period. From many parts of the territory remains of the mammoth have been collected. In depressions of the great San Augustine plains east of Datil large numbers of teeth and bones are found where the great mammals were mired while drinking. It would appear that the period during which these elephants roamed our plains has not long passed. In the flood plain of the Rio Grande near Bernalillo several teeth have been found and one fine example is in the university museum. Several small gasteropod shells were taken from the river clays near Algodones and among these Mr. E. H. Ashman identified Sacciura overa, Say and Leucocheila fallox, Say. Doubtless many interesting forms will reward a diligent search.

Petrography.

In the region covered by the map there are comparatively few eruptive rocks and these belong to the later series.

Basalts.

Remarkable uniformity characterizes the basalts of this region though they pass from the extreme of scoriaceous to massive and amygdaloidal types. The chemical composition seems to have been very constant. Dutton and other writers report two distinct periods of basaltic flow but we have so far encountered no evidence of such an interval between the later and earlier flows as he indicates, in this region. The flows are all post-Tertiary and well preserved. Successive flows occurred and intervals are filled with volcanic sand and tufa but there is no evidence of long periods intervening.

1. *Basalt from the Albuquerque volcanoes.* These cones, as described above, are conspicuous features in the landscape as seen from Albuquerque and break the uniformity of the western horizon.

The sample is somewhat vesicular but between the blebs the structure is compact and but slightly amygdaloidal. The

color is black to dark brown with small phenocrysts of plagioclase and grains of olivine. In the section the largest elements are polysomatic grains of the plagioclase with conspicuous albite twins. The mineral is fresh and in definite crystal form. The extinction angle at right angle to the albite twinning plane is near $35°$ and indicates a composition like anorthite but the optical behavior is negative and the high colors of polarization suggest laboradorite. Smaller lath-shaped crystals of plagioclase fill the deep colored magma. Next to the first order plagioclase, the most conspicuous elements in the section are the brilliantly polarizing grains of olivine some of which preserve their crystalline form. The olivine is remarkably fresh and contains few inclusions. The augite which is of the basaltic type plays a very insignificant rôle being restricted to grains scattered in the interstices of the small plagioclase crystals. The magma is granular and opaque and contains much magnetite and brown suffusions. Amygdules of isotropous and amorphous materials occur sparingly.

In order to show the extremes of structure the following descriptions are appended derived from basalts found along the Rio Grande east of the Cochiti range selected to show the latest and earliest of several flows at that place. It will be seen that there is evidence of some alteration in the lower member. The intervals are irregularly filled with volcanic and scoriaceous material.

No. 495. Lowest Member of a Series of Basaltic Flows in White Cañon, south-west of Santa Fé. A somewhat vesicular massive basalt with numerous spots of reddish decomposition, imparting a rusty color to the entire rock, strongly contrasting with the fresh and glossy black appearance of the upper flows of the same series. In many places large zeolitic inclusions occur, having a radiated structure and a whitish or greenish color, which determines it, apparently, as analcite. The less altered portions show the feldspathic elements to be unaltered. The whole crystalline body of the rock is made up chiefly of plagioclase of two distinct orders. Those of the first order are large, well-formed crystals, exceeding those of the magma many

times in size. These larger crystals are mostly fresh and unaltered, with high extinction angles, suggesting anorthite. The twinning phenomena are very well developed, according to both the Albite and Carlsbad laws. The mass of the rock, however, is made up of small, lath-shaped crystals, having the same optical characters as those first described. These smaller crystals betray a tendency to a fluidal arrangement, and the larger plagioclases are sometimes broken by transverse fracture lines, apparently as the result of internal tension. Next in point of abundance are scattered irregular crystalline grains, often in polysomatic groups, which are of an intense red color and permeated by irregular crevices. This mineral polarizes in shades of red and brown, behaving much like hematite. In a few cases there is a suggestion of the original olivine. The augite consists of minute scattered grains in the interstices of the second order of plagioclases. Grains of magnetite are freely scattered throughout the section. The cavities are frequently partially filled in with amorphous material.

No. 504. Massive portion of the uppermost flow at White Rock Cañon. Hand-sample an intensely black, homogenous rock with a splintery fracture and occasional gas pores. To the unaided eye, the ingredients appear quite unaltered. Portions of this flow are laminated and break into schistose fragments. Thin section densely sprinkled with minute black granules, giving to the section a peculiar opaque character. The largest ingredients are well formed, tabular crystals appearing in section as elongated rectangles, having a rough surface, brilliant polarization, and intersected by conchoidal crevices, tending to lie transversely to the longer axis. These crystals are often much broken and penetrated by the magma. The sections extinguish parallel to the longer axis and are little altered or decomposed, and constitute a remarkable occurrence of olivine. Occasional crystals of the same material have truncated planes. Plagioclase is abundant in crystals of two orders: the larger being very generally corroded and filled with intersections of the ground mass and particularly augite grains; the plagioclase of the second order is in small, lath-shaped crystals, is less altered, and

forms the bulk of the section. Both series seem to be of anorthite. The augite, as in the preceding instances, is chiefly in scattered grains; although larger crystals are not wanting. Magnetic iron is scattered throughout the ground mass; and, in a few instances, hematite is encountered. The granular suffusion from the ground mass renders a minute study of the rock difficult.

Isolated Trachyte Cones in the Rio Grande Valley.

The isolated volcanoes of the Rio Grande valley are nearly all basaltic and it has usually been assumed that all such minor peaks are of this character. After noticing that there are at least two classes as regards the relation of these lavas to the Tertiary strata of the valley the enquiry was natural whether there might not be a distinction in composition between those that are found in connection with superficial flows and those that have been buried under Tertiary sands and marls. The larger ranges like the Socorro and Limitars toward the close of their active existence passed through a trachyte-rhyolite stage and rocks of the silicious series are found perforating the earlier andesites but the apparent relations of the small isolated volcanoes spoken of is with the recent basalts and it is not always easy to determine a difference between the materials and those of altered portions of the basalt cones.

An instance of such a buried cone is afforded by a volcanic cone on the west side of the Tertiary mesa west of the Rio Grande opposite Albuquerque. This hill has evidently been buried by the material of which this mesa was formed and has been re-excavated by the Rio Puerco. Unlike the recent volcanoes on the east side of the mesa on the banks of the Rio Grande, some six miles distant, this cone is not associated with superficial flows but all such evidences of overflow have been removed by erosion, apparently prior to the deposition of the Tertiary sands and marls. The subsequent denudation has left exposed the irrregular neck and boss-like protrusions from the base.

A considerable variety in the rock is apparent to the eye

and the relations of the intrusive to the surrounding stratified rocks may prove a matter of much interest. The latter are sandstones usually of a whitish color but, where in contact with the igneous rocks, often greatly reddened and altered. The mutual influence of the two elements is seen on the one hand in the production of jasper and other forms of silica, and on the other by the hastened decomposition of the igneous rock. This volcano is marked on the land office map as "red sandstone hill." The typical rock of the series is a red trachyte, number 577. This sample is taken from a large boss near the base but is characteristic of the main elevation as well. The hand sample is of a purplish to brownish red or reddish grey color with yellowish flecks and glistening phenocrysts of feldspar. Phases of the rock are a deep brick red. The texture is rough, with numerous small irregular openings and spongy portions. Evidence of some disintegration of the feldspars is patent to the unaided eye.

The section is fairly typical of a trachyte without free quartz but with feldspars of two or three orders, and a small amount of scattered mica. The largest crystals are of relatively little altered plagioclase usually occurring in large polysomatic groups. These are not numerous but are very striking. The measured angles on either side the twinning plane were 14–16 and 15–17 in the two cases where most satisfactory readings were taken, suggesting, in connection with the association, albite and with this agrees the positive optical behavior. Next in order of size are orthoclase crystals which tend to be much altered and filled with interpositions. Some of these crystals seem to be almost completely altered to a granular material but they have not lost the polarization nor twinning phenomena. Frequently the vacuolization and interpenetration of the orthoclase has only proceeded to an irregular area in the centre of the crystal where the substance is unaltered. In other cases the alteration zone is strictly limited to a band near the periphery of the crystal. Zonary structure, which in some cases simulates the plagioclase twinning, is frequent and seems to pertain to the albite. The smaller rods which fill the magma seem

to be chiefly orthoclase though plagioclase twinning can be seen in many of them and it is probably unsafe to draw definite conclusions from the absence of such twinning in small crystals. Next in importance is the bronze mica which occurs both in large crystals and smaller scales, but neither is abundant. In the smaller scales the mica is nearly completely altered. Iron lined cavities with ribs of the iron preserve the outlines of what may have been hornblende crystals but no recognizable specimens were seen. The granular magma is pale red or yellowish, evidently iron-stained. Scattered magnetite is present throughout the section.

No. 574 from the central portion of the peak is a typical trachyte but evidently has suffered much alteration. Kaolinization of the feldspar is apparent to the eye while the mica stands out in evident scales. The section bears out the testimony of the hand sample. The mica is in delicate, often flexuous plates and polarizes with almost unexampled brilliancy. The feldspars are mostly altered, often leaving cavities filled with kaolin, or if not so completely altered, the polarization is lowered so that the transparent contents react almost as if isotropous. Orthoclase is the only identifiable feldspar.

Number 578 is a very porous light-colored rock lying near the contact with the penetrated sandstone. The disintegration has been very complete so that the orthoclase has been nearly wholly removed leaving cavities that are usually unfilled. Under the microscope a few grains of the orthoclase remain visible and mica flakes are scattered through the relatively homogegeneous magma. The dark ingredients are in minute dots in the magma and the magnitite is less abundant. The micas are paler and less pleochroic than in number 577.

Number 576 is a very light brecciated phase near the sandstone and is like the above in a highly disintegrated state. The mica is nearly entirely altered to a black aggregate.

Several other sections of various phases of these rocks show not only stages in the process of disintegration but show that proximity to the country rock was a very important element in that process. A section of the sandstone adjacent to the cone,

which is a moderately coarse white sandstone apparently of Cretaceous age, exhibits rounded grains of quartz mixed with similar grains of orthoclase having the twinning and other optical characters well preserved. Some of the feldspars have undergone saussurritic disintegration while others are quite clear. The abundant cement is a reddish brown (ferrugineous) material but seems only to impart a yellowish cast to the hand sample. Occasionally the feldspars preserve the rectangular contours of the cleavage fragments.

Rio Grande and Rio Puerco Flood Plains.

The flood plains of the Rio Grande and Rio Puerco contain many thousands of acres capable of cultivation. This land is of inexhaustable fertility and is adapted to the production of a fine variety of fruits and vegetables. It is especially adapted to the raising of alfalfa and grain. When the new irrigation now in process of construction shall be complete it is estimated that it will bring over 20,000 acres under irrigation between Algadones and Albuquerque and the same system will be extended southward to Isleta. An organization has been affected for the establishment of a reservoir system in the Rio Puerco valley. The great difficulty here will be the enormous amount silt which would tend rapidly to fill and so destroy any reservoir system. The land is remarkably fertile and the presence of lignite and probable existence of oil will ultimately make this a prosperous region.

For the following notes on building materials and practice we are indebted to architect C. E. Cristy.

Building Materials.

The materials used for building in Albuquerque consist of wood, stone, brick and adobe.

Dimension lumber is brought from the saw mills about Albuquerque and also from Glorieta and in special cases Oregon pine is brought in. Some of the finishing lumber comes from Chicago, some from Arizona and some from California. Most of the sash and doors come from Chicago. California redwood shingles are entensively used.

In the mountains east of the city is found an abundance of granite building rock that is used for foundations but it is so hard that the difficulty of dressing it prohibits its use in anything but ordinary rubble work and door sills. Sandstone may be obtained in any quantity and of various qualities and colors within a comparatively short radius from the city.

As to the brick problem, it has not yet been solved to the satisfaction of those who have given long years to the faithful study of the clays and the best way of mixing them and the drying and burning of the brick. Most of the brick buildings are built of a hand made mud brick, the fuel for burning being wood. There are some buildings faced with a handsome pressed brick, brought from either Kansas City or Golden. A sample of Santa Fé brick has been shown here but at this date there are no completed buildings made from it. Socorro bricks are coming more into favor because of the improvement in the evenness of their color. They have always received the highest award as a hard, homogenous, well-burnt brick, but the uneven color has been against them. Once this is overcome they will furnish as fine a building material as could be asked for.

Adobe is made from a clay that is wet and pressed into moulds, the usual size being 4x8x16 inches. They are turned from the moulds upon the ground and sun dried. Sometimes straw is put into the mud. These adobes are laid up, for the most part, in mud mortar and plastered over with the same material; but in some cases they are laid up in lime mortar and plastered. The outside walls are made 16 inches thick while the inside partitions are laid the eight inch way.

A good supply of fresh burnt lime can be had from kilns near the city and any standard brand of plaster can be obtained through local dealers. Frame houses, properly built are very comfortable and durable but where the siding is put directly on the studs and the sills rest on posts the result is a very hot summer house and a cold winter one. In brick veneer houses the same may be said, that is, if properly constructed they make a fine appearing structure and are perfectly solid; the unseemly cracks showing in some cases are due to faulty

construction and not to our material. A comfortable but expensive method has been used where an adobe house has been completely sided, making a cool interior, and giving to the exterior the appearance of a frame structure.

Thus it may be seen that while we have not the unlimited variety of building materials that are to be found in larger, older cities, yet we are not without a choice when the amount to be expended is commensurate with the requirements of the proposed building.

To the above we may add a few notes upon building materials :

Clay. Little has so far been done in the study of our clays but enough is known to make it clear that the territory is well supplied with clay for all purposes. The base of the brick so far made in the Rio Grande valley is what is locally called asequia clay, that is clay collected in the flood plain. There is the greatest diversity in different deposits due to the fact that at different stages of water material is brought in from different tributaries as thus in one case a clay high in clay base may be deposited while in another the alkalis may be dangerously high. Disintegration of the trachyte tufas make a very fusible clay while many of the clays are highly siliceous. The color is also variable even in adjacent beds so that the one may furnish the material for a light buff or cream brick and an adjacent one for a red or brown brick. In the neighborhood of Albuquerque, clays are derived from two sources. First, the flood plain or asequia clay beds and, second the mesa beds. The latter are very pulverant and crumble easily but have a dark color in local favor. The mesa clays, however, contain large quantities of marl in fragments of various size and as no pains is taken to screen the clay the lumps of lime disintegrate on the addition of water and the bricks burst. This "popping" is a constant source of disfigurement and will result in destroying some expensive buildings which, through the criminal neglect of the builders, have been constructed of such material. The mesa clay is sometimes used to temper the asequia clay and by this means the color is heightened. When screened to remove the marls

the addition is unobjectionable but the color desired may be secured by adding iron oxide in the form of one of the red earths on the market. The natural color of the best flood plain clays is a rather pretty "golden buff" but other clays in the same flat where thoroughly impregnated by alkali produce a white or creamy buff brick. One serious objection to all the brick burned from the valley clays grows out of the discoloration in burning. In those parts of the brick exposed to the air in drying or in a kiln a white crust or film is formed which gathers on the exposed surface in an irregular and most disfiguring manner. Finger marks where pressure was brought to bear on the brick while wet will be discolored in the same way. The discoloration has ruined the sale of otherwise perfect brick for many years in the Rio Grande valley. The film has been supposed to be due to fumes in the kiln during burning but it is noticeable that the color is worse in pressed brick and that the brick exposed to rapid drying or to the moist vapors in the kiln are the most seriously affected. Where the brick are covered or protect each other the color is absent. Where brick have been made from the mesa marl, as has been attempted in ignorance of the composition, the whole kiln will be affected. On the newly scraped clay beds the efflorescence appears in a few hours and in the neighborhood of the clay for white brick shallow pools are saturated with saline and alkaline materials composed of chloride of sodium, chloride of potassium, sulphate of soda, sulphate of potassium (?), nitrate of potassium and calcium chloride (?). The nitre is quite abundant in some cases. The same difficulty has been encountered at Socorro where the brick are of excellent quality otherwise. The clay of the flood plain is tempered with from one third to two thirds sand, being an excess but apparently necessary in these cases. The heat is estimated by the kiln men at about 1200 degrees and they state that fusion takes place at about 1300 degrees. The addition of some good clay base would improve the product and such material would be found in the Cretaceous clays on the Rio Puerco or perhaps near Coyote cañon. Kaolin such as is used at Socorro seems not to be within reach at Albuquerque. This ma-

terial is found in Socorro mountains for example as the product of interaction between the andesites and the overlying trachyte. At Socorro also are found very good clays in a peculiar zone of the Carboniferous. Fire clay beds are found in immediate proximity to shales with lepidodendrids like those shown in Plate XXXIII. Red clays from the Permian or Jura-triassic also supply a useful variant. At Las Vegas the bluish shales of the Cretaceous form an excellent base for a light red or buff brick although precaution is necessary to remove the bands of pyrites and fat clay to prevent discoloration. The following analyses of local clays will be useful. The analysis of clay No. 24 shows it to contain excess of clay base and it would probably be a useful addition to many asequia clays. Only small quantities would be needed as it is deficient in free silica.

Number	22	23	24	789	667	515	496	495
Silica, free	48.33	21.54	9 47					
Silica, combined	28.21	49.12	50 22	64.02	29.72	60.76	44.48	49
Alumina	5.90	14.58	22.26	17.34	11.94	19 69	26.32	20.82
Iron (Fe_2O_3)	3.41	.84	2.07					
Magnesia	trace	——		1.06	1.83	.79	4.43	3.48
Lime (CaO)	1.54	4.75	3.83	1.98	32.11	5.87	13.15	9.61
Water combined	2.	2 75	3.85					
Moisture	4 28	(1.04)	(6.4)					
Carbon dioxide	3.16	.67	2.26					
Potassium	2.43	2.41	2.35					
Sodium	.80	.68	.84					
Clorine			2.53					
SO_3			trace					
Iron Fe_3O_4				5.72		7.54	11.03	13.67
Iron FeO					26.48			
	100.06	100.18	99.68					

Analyzed by D. W. Johnson.

No. 22. Asequia clay from Old Albuquerque. Hon. E. S. Stover.

No. 23. Asequia clay from Buttman's pits. With marl nodules.

No. 24. Red clay (Tertiary) from Bernalillo.

No. 789. Supposed lava containing corn. Fused adobe.

Nos. 667, 515, 496, 495. Partial analyses of basalts from White Rock Cañon.

No. 667. Slag from Rio Grande smelter.

DESCRIPTION OF PLATES.

PLATE XXVII.

Figs. 1-2. Buchiceras swallovi, Shumard. Dorsal and lateral views of gibbous form.

Figs. 3-4. Buchiceras swallovi, var. puercoensis, var. n. Dorsal and ventral views. Both forms occur in septaria concretions of the Colorado formation in the Rio Puerco valley.

PLATE XXVIII.

Fig. 1. Prionocyclus woolgari, Mantell. Sandstones north-east of San Francisco in Rio Puerco valley. Tres Hermanos sandstone above gasteropod zone.

Figs. 2-3. Placenticeras costatus, sp. n. From septaria concretions near Punta de la Mesa, Rio Puerco valley.

Fig. 4. Harpa ? occidentalis, sp. n. East of Sandia mountains.

Fig. 5. Undetermined gasteropod.

Fig. 6. Turritella whitei, Stanton.

PLATE XXIX.

Fig. 1. Rostellites ambigua, Stanton.

Fig. 2. Volutomorpha (?) nova-mexicana, sp. n. Una de Gato.

Figs. 3 and 5. Rostellites dalli, Stanton. Fox Hills group.

Fig. 4. Vanikorpsis tuomeyana M. and H. Fox Hills.

Fig. 6.

Figs. 7, a and 6. Gyrodes depressa, Meek. Fox Hills strata.

Fig. 8. Ostrea franklini, Coquand ?

Fig. 9. Cf. Ostrea translucida, M. and H. See Plate XXIV, Figs. 7-10. Gasteropod zone below Tres Hermanos sandstone.

PLATE XXX.

Fig. 1. Inoceramus fragilis, H. and M.

Fig. 2. Inoceramus sp. Caballo mountains.

Fig. 3. Gryphaea vesicularis, Lam.

Fig. 4. Inoceramus fragilis ? hinge view. Fox Hills.

Fig. 5. Mactra pulchella, sp. n.

Figs. 6 and 7. Caryates veta, Whitfield. Septaria concretions.

Fig. 8. Ostrea sp.

PLATE XXXI.

Fig. 1. Pinna petrina, White. Septaria concretions.

Fig. 2. "

Fig. 3. "

Fig. 4. "

All the figures are one half natural size.

PLATE XXXII.

Figs. 1, 2. Pholadomya subventricosa, M. and H.

Figs. 3, 4.

Fig. 5. Tellina (?) perlata, sp. n. Fox Hills group. East of San Antonio.

Figs. 6, 7. Tapes cyrimeroformis, Stanton. Septaria concretions.

PLATE XXXIII.

Fig. 1. Lepidodendron sp.

Fig. 2. Lepidodendron sp.

Fig. 3. Lepidodendron sp.

Fig. 4. Lepidodendron sp.

The above are all derived from fire clay beds east of Socorro.

Fig. 5. Liopistha concentrica, Stanton. This is the form described by Stanton as L. elongata.

Fig. 6. Mactra formosa, Meek.

Fig. 7. Ostrea translucida (?)

Fig. 8. Rostellites dalli, Stanton.

Fig. 9. Pyropsis bairdi, M. and H.

Fig. 10. Unidentified.

Fig. 11. Cardium pauperculum, Meek.

Fig. 12. Unidentified. Figs. 5-12, inclusive, are from sandstones adjacent to the coal at Carthage.

PLATE XXXIV.

Figs. 1, 2. Ostrea glabra, White. Shales east of Caballo mountains. Laramie?

Figs. 3, 4. Inoceramus fragilis, H. and M.? Casts of interior. Sandstone at Punta de la Mesa, near San Ignatio.

Fig. 5. Inoceramus fragilis? Same locality as above.

Fig. 6. Pyropsis bairdi, M. and H. Above lignite beds. Sandstone east of Punta de la Mesa.

Figs. 7-10. Ostrea translucida, M. and H. Different individuals as casts of the interior. Gasteropod zone below Tres Hermanos sandstone. Rio Puerco valley.

PLATE XXXV.

Fig. 1. Cardium sp. Upper Fox Hills.

Figs. 2-7. Idonearca (?) depressa, White. Upper Fox Hills. Rio Puerco valley.

PLATE XXXVI.

Figs. 1, 2. Plicatula hydrotheca, White. Views of opposite valves.

Figs. 3, 4. Plicatula arenaria, Meek. Under and upper valves.

Fig. 5. Lima utahensis, Stanton. Cast of large left valve.

Fig. 6. Camptonectes platessa, White. Right valve.

Figs. 7-10. Avicula gastrodes, Meek.

PLATE XXXVII.

Fig. 1. Inoceramus deformis, Meek.
Fig. 2. Inoceramus labiatus, Schloth.
Fig. 3. Inoceramus gilberti, White.

PLATE XXXVIII.

Figs. 1-4. Barbatia micronema, Meek (sp.).
Fig. 5. Nemodon sulcatinus, E. and S.
Figs. 6, 7. Goldia subelliptica, Stanton.
Fig. 8. Solemya ? obscura, Stanton.
Fig. 9. Nucula coloradoensis, Stanton.
Figs. 10-13. Crassatella excavata, Stanton.

PLATE XXXIX.

Figs. 1-3. Cyrena securis, Meek.
Fig. 4. Cyrena sp.
Fig. 5. Veniella goniophora, Meek.
Figs. 6-9. Veniella mortoni, M. and H.

PLATE XL.

Fig. 1. Donax cuneata, Stanton.
Fig. 2. Donax oblonga, Stanton.
Fig. 3. Tellina modesta, Meek.
Figs. 4-7. Tellina (Palæomœra) whitei, Stanton.
Fig. 8. Tellina isonema, Meek.
Fig. 9. Tellina (?) subalata, Meek.
Figs. 10-11. Siliqua huerfanensis, Stanton.
Figs. 12-13. Pharella ? pealei, Meek.

PLATE XLI.

Fig. 1. Pholadomya papyracea, M. and H.
Fig. 2. Pholadomya coloradoensis, Stanton.
Figs. 3-4. Anatina lineata, Stanton.
Figs. 5-7. Liopistha (Psilomya) meeki, White.
Figs. 8-10. Liopistha concentrica, Stanton.
Figs. 11-12. Liopistha (Psilomya) elongata, Stanton.

PLATE XLII.

Fig. 1. Amauropsis utahensis, White.
Figs. 2-4. Amauropsis bulbiformis, Sowerby.
Figs. 5-6. Sigaretus (Eunaticina) textiles, Stanton.
Figs. 7-8. Mesostoma occidentalis, Stanton.
Fig. 9. Eulimella ? funicula, Meek.
Figs. 10-11. Chemnitzia ? coalvillensis, Meek.

PLATE XLIII.

Fig. 1. Aporrhais (Gonocheila) castorensis, Whitfield.
Fig. 2. Aporrhais (Perissoptera ?) prolabiata, White.
Figs. 3-4. Anchura (Depanocheilus) ruida, White.
Figs. 5-6. Lispodesthes nuptialis, White.
Figs. 7-11. Pugnellus fusiformis, Meek.
Fig. 12. Tritonium kanabense, Stanton.
Fig. 13. Fusus shumardi, H. and M.
Fig. 14. Fusus gabbi, Meek.
Fig. 15. Tritonidea ? huerfanensis, Stanton.

PLATE XLIV.

Figs. 1-3. Rostellites gracilis, Stanton.
Fig. 4. Pleurotoma ? hitzi, Meek.
Figs. 5-8. Actaeon propinquus, Stanton.
Figs. 9-11. Haminea truncata, Stanton.

PLATE XLV.

Fig. 1. Mortoniceras? vernilionense, M. and H.
Fig. 2. Scaphites larvæformis, M. and H.
Fig. 3. Scaphites vermiformis, M. and H.
Figs. 4-7. Scaphites warreni, M. and H.
Figs. 8-10. Scaphites ventricosus, M. and H.

PLATE XLVI.

Fig. 1. Scaphites ventricosus, M. and H.
Figs. 2-4. Scaphites mullananus, M. and H.

PLATE XLVII.

Fig. 1. Allorisma subcuneata, Meek. Upper layers of massive lime (Permo-carboniferous) Dog Cañon. Sacramento mountains.

Figs. 2-3. Spirifer imbrex. Lake Valley. Burlington.
Fig. 4. Strophomena rhomboidalis, " " "
Fig. 5. Athyris lamellosa, " " "
Fig. 6. Rhynchonella, " " "
Figs. 7-7a. Spirifer grimesi, Hall " " "

Fig. 8. Polypora coyotaensis, sp. n. Flint Ridge shales near Coyote Springs.

Fig. 9. Phillipsia, sp. n. Flint Ridge shales near Coyote Spring.

Fig. 10. Phillipsia major, Shum. Upper layers Permo-carboniferous, No. 654.

Fig. 11. Phillipsia, sp. n. Sandia limestone near Coyote Spring.

PLATE XLVIII.

Correlated sections applicable to the region described and adjacent exposures. Data on the plate itself.

PLATES XLIX-LII (Inclusive)

These illustrations are intended to accompany the section on building materials and to indicate the use made of the available resources. The churches are for the most part built of local brick or flagstaff sandstone. The Grant block (Plate L) is of Kansas City red brick with buff trimmings. The fine building of the commercial club is wholly built of Flagstaff red sandstone. (Jura-triassic?) The school houses are built of local red brick. Several private residences are shown dating from an earlier period of the city's growth.

PLATE LIII.

Fig. 1. Lignite bands in upper (Fox Hills) cretaceous. Mesa Isleta mono cline, Rio Puerco valley.

Fig. 2. Same as above, showing eroded pinacles of white sand below the lignite.

PLATE LIV.

Fig. 1. Mesa Isleta monocline, from a distance.

Fig. 2. Concretionary zone in Santa Fé marls. West side of Albuquerque mesa, near Fig. 1.

PLATE LV.

Fig. 1. Punta de la Mesa sandstone west of the Coralles-Cabezon road, a few miles south-east of Cabezon.

Fig. 2. Vermilion beds as exposed in valley-south-west of Serrita mesa. Top of chocolate beds showing at base.

PLATE LVI.

Fig. 1. Serrita mesa, southern end of Nacimiento range. Gypsum beds showing at base. The figure does not clearly show the stratification which is very distinct to the eye.

Fig. 2. Upper Cretaceous shales, sands and lignite west of the north end of Albuquerque mesa. In the coal series.

PLATE LVII.

Figs. 1 and 2. Eroded Santa Fé marls, west side of Albuquerque mesa.

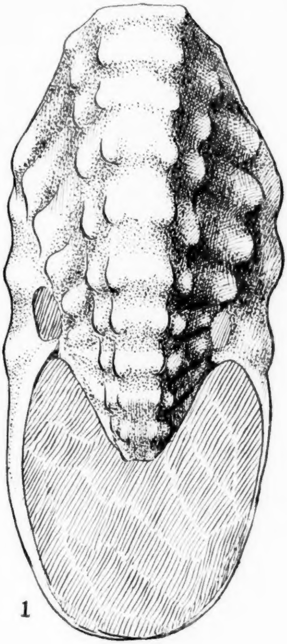
PLATE LVIII.

Fig. 1. Tres Hermanos sandstone, showing the large concretions.

Fig. 2. Same sandstone with layer of indurated sandstone above.

1

3



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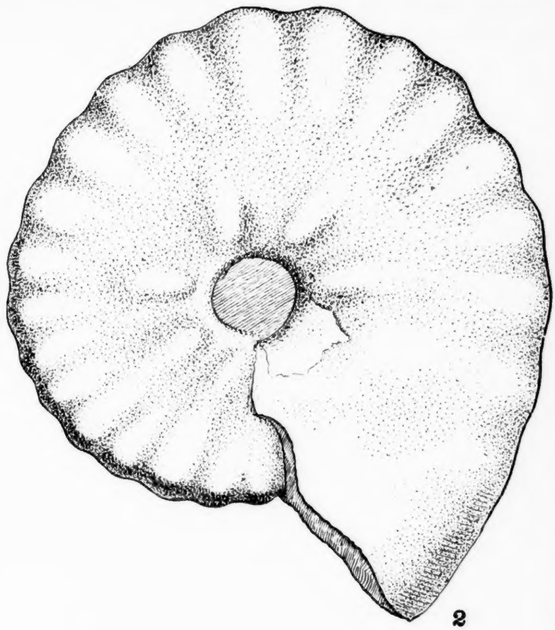

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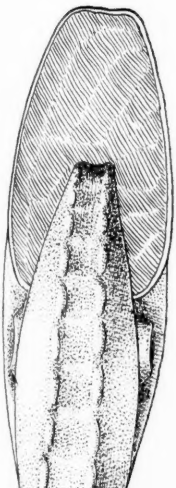

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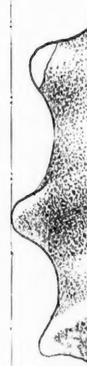

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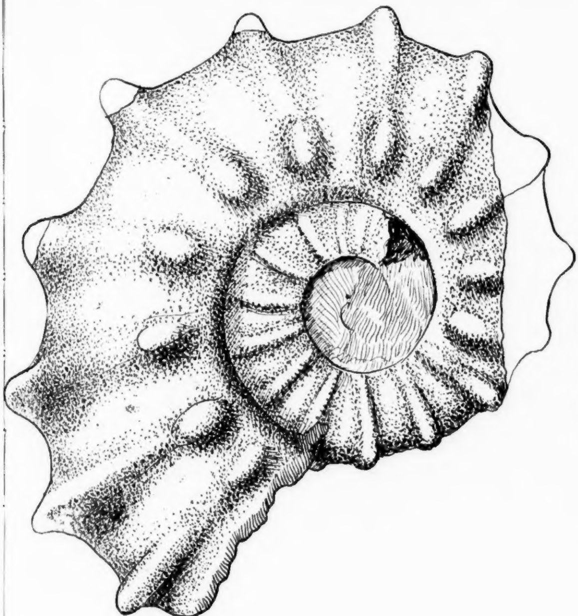

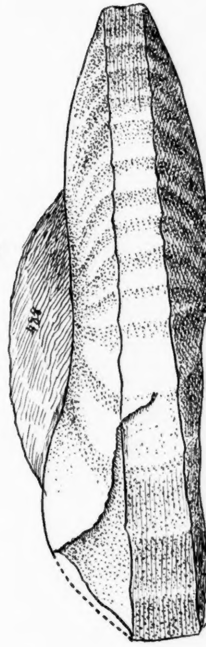

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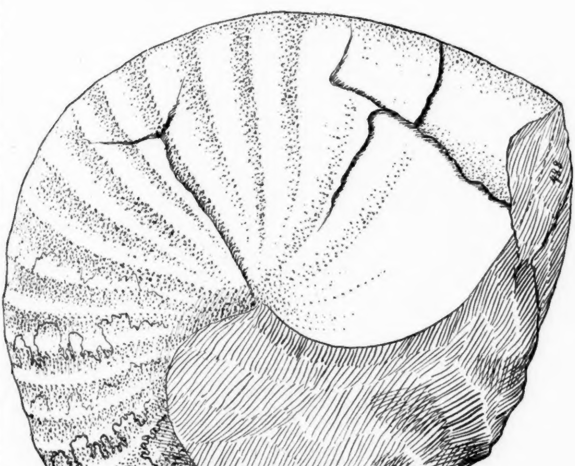

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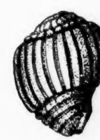

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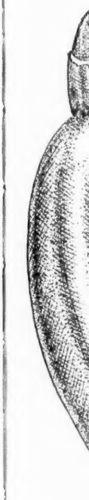

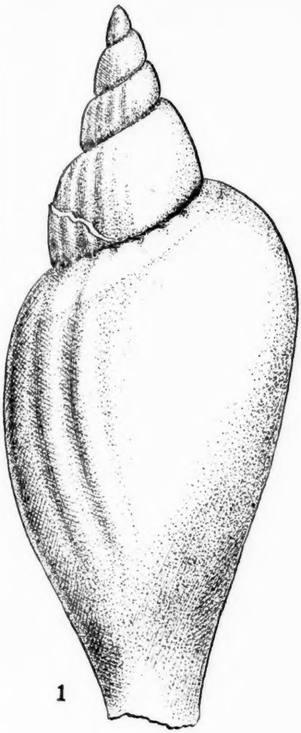

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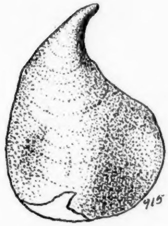

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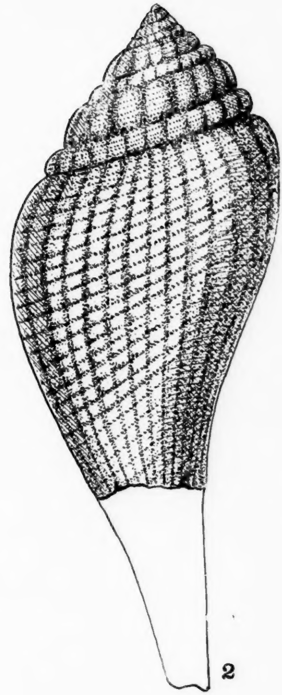

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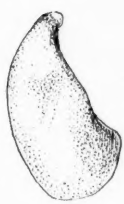

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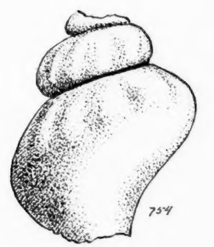

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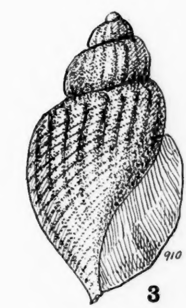

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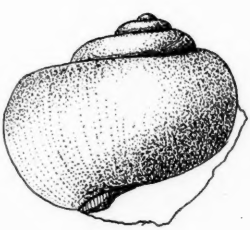

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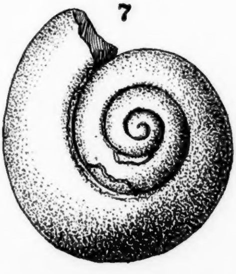

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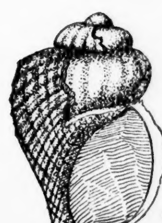

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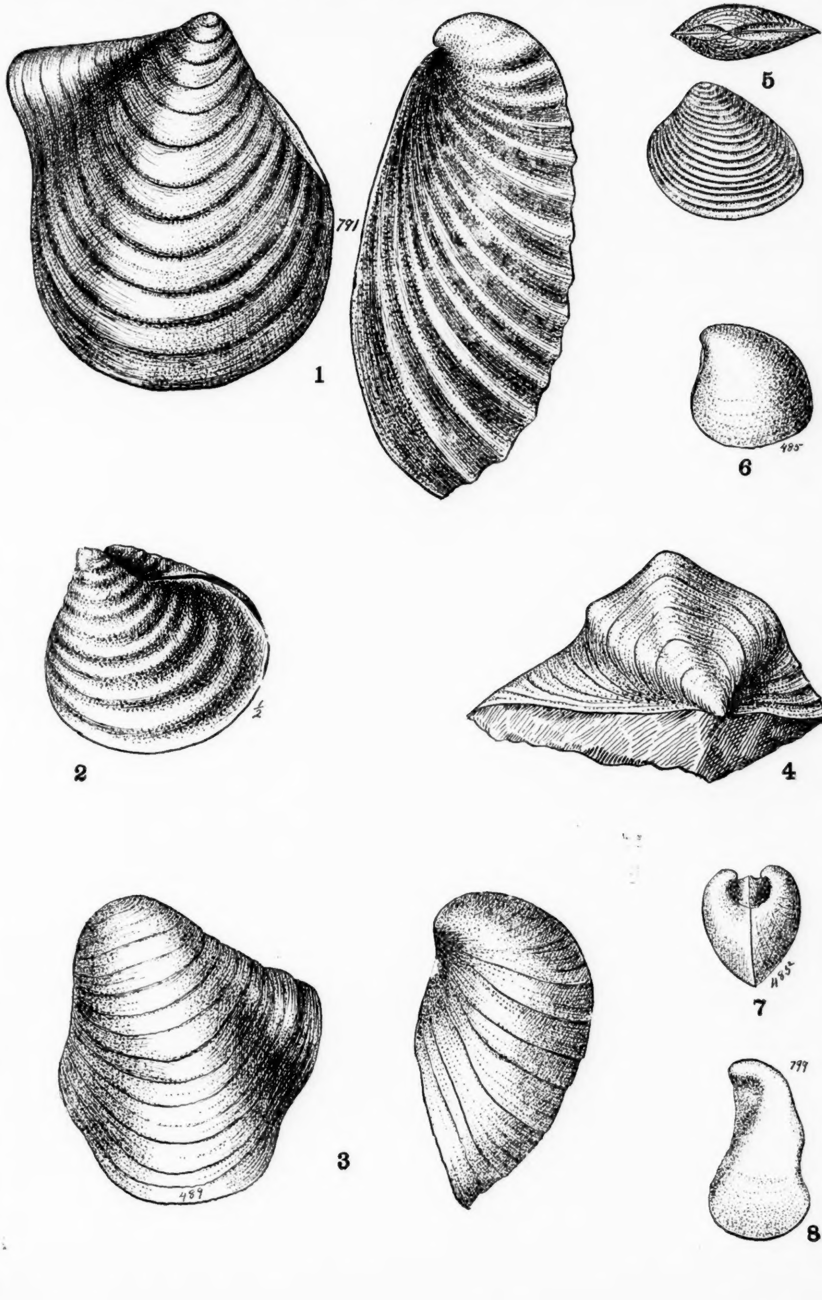
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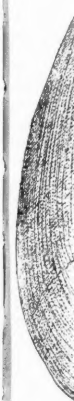

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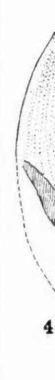

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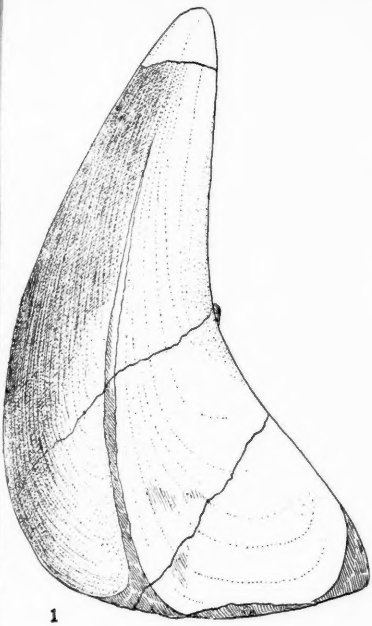

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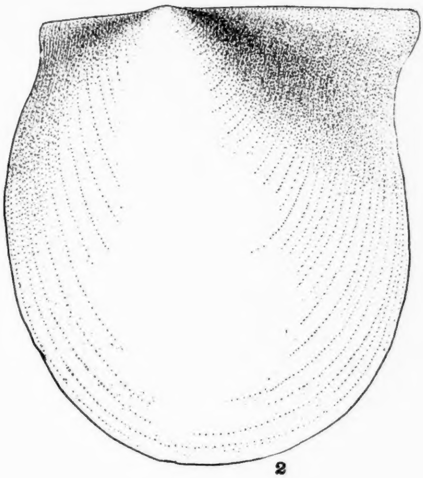

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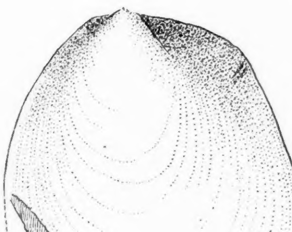

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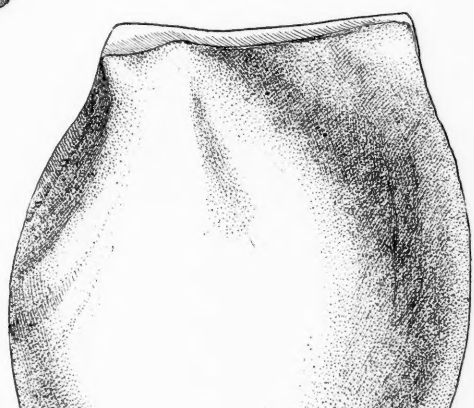

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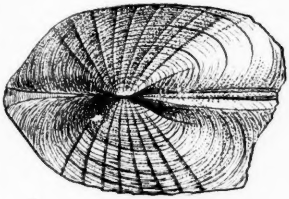

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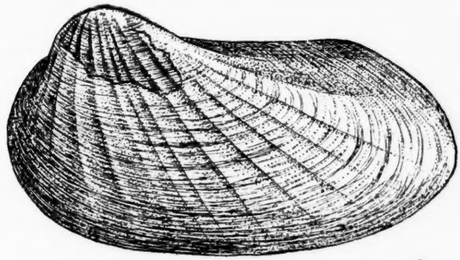

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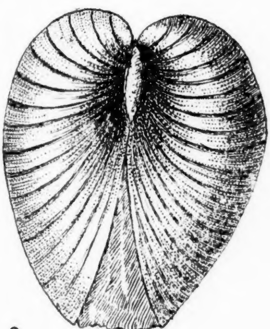

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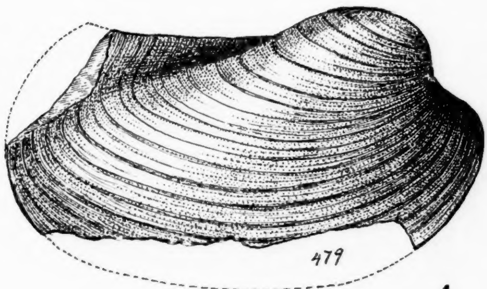

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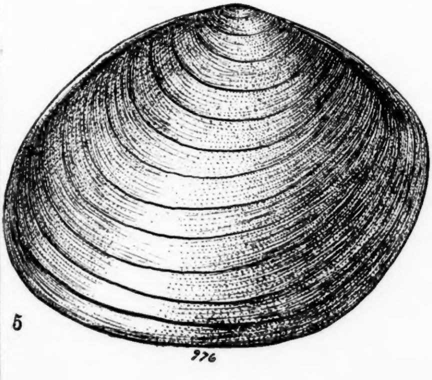

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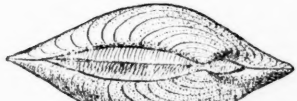

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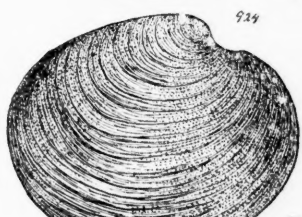

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Fig. 1.

Fig. 2.

Fig. 3.

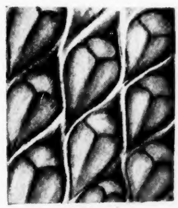

Fig. 4.

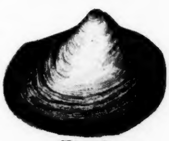

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 9.

Fig. 8.

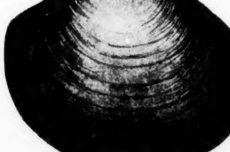

Fig. 10.

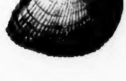

Fig. 11.

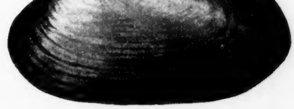

Fig. 12.

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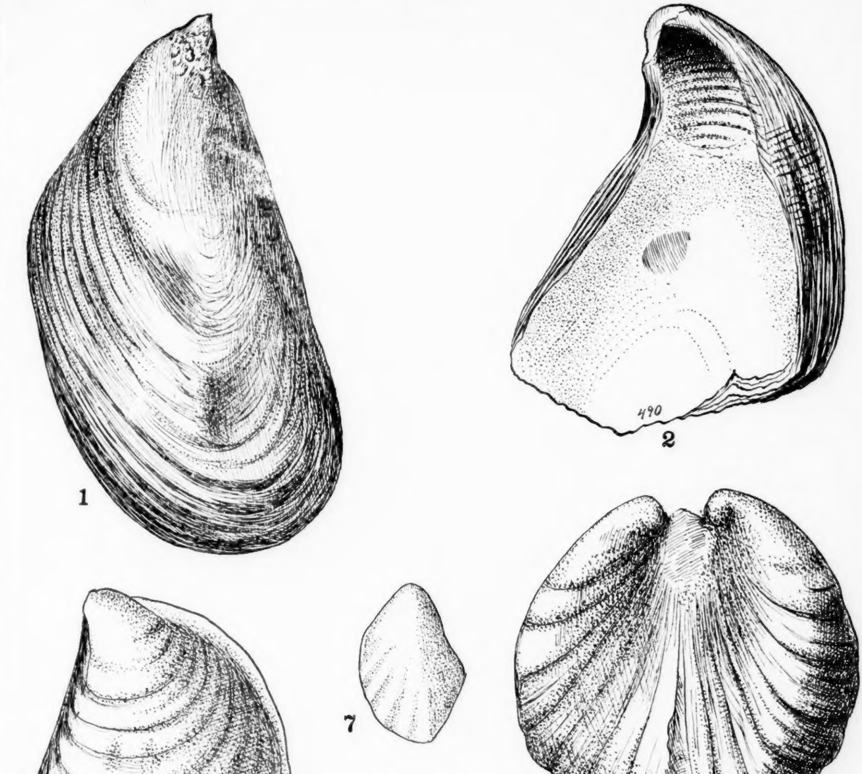
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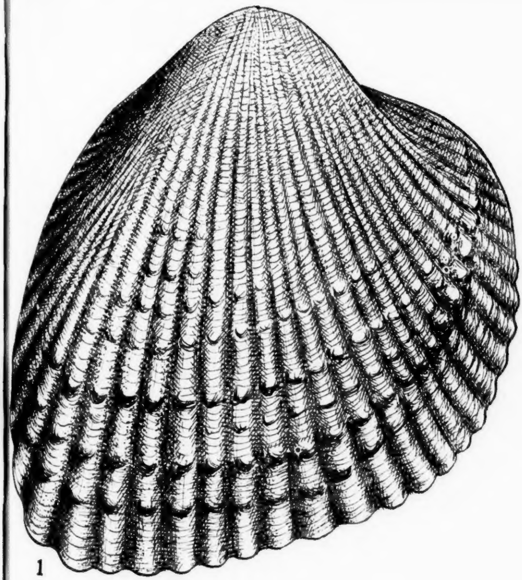
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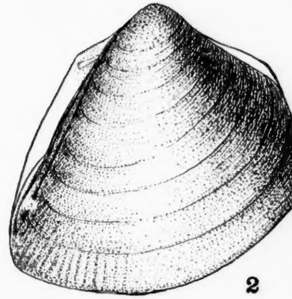
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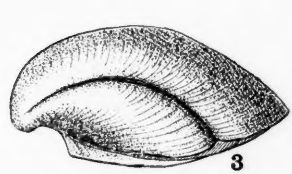
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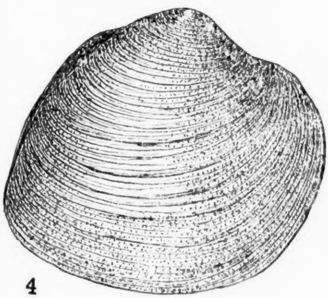
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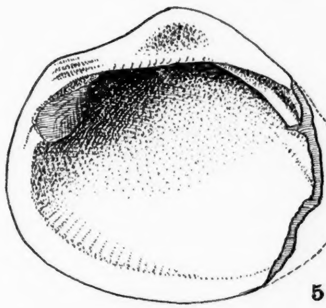
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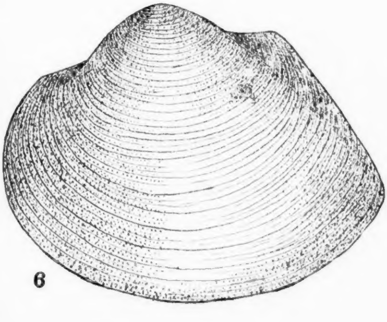
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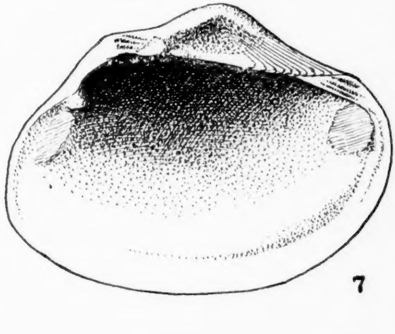
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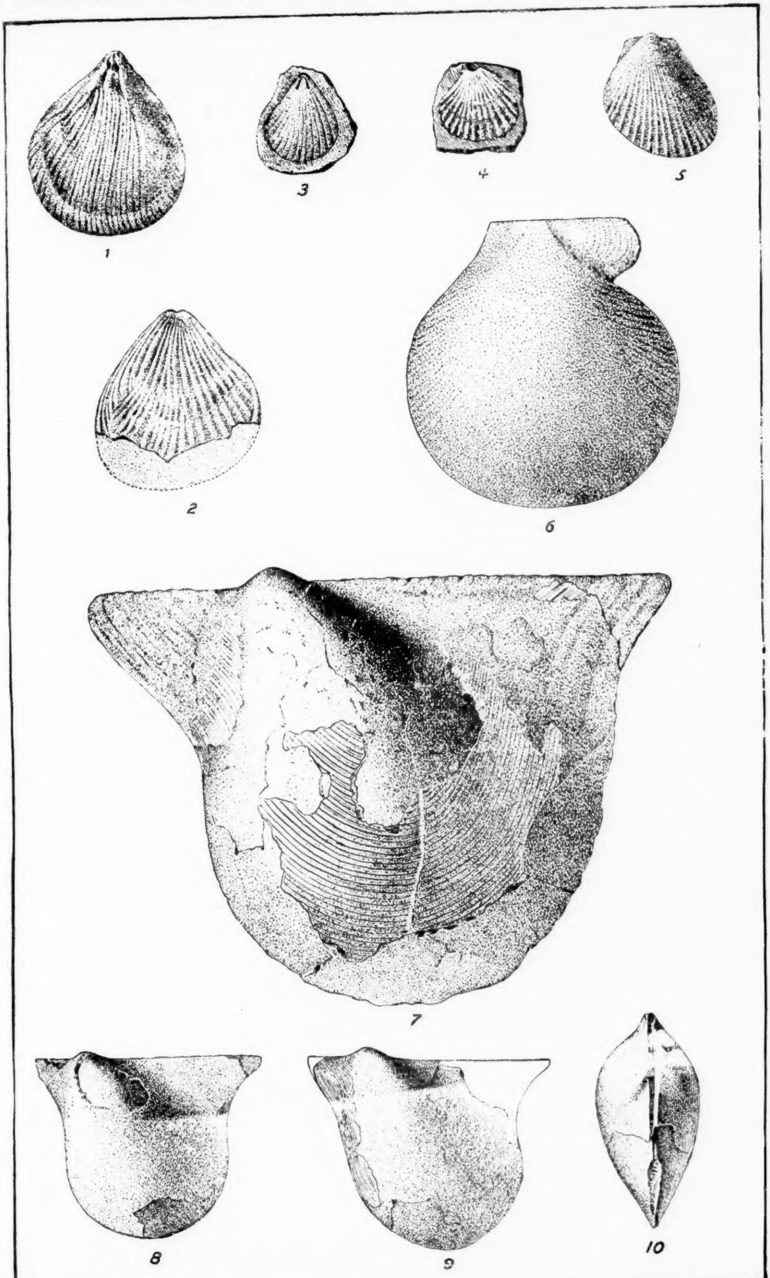
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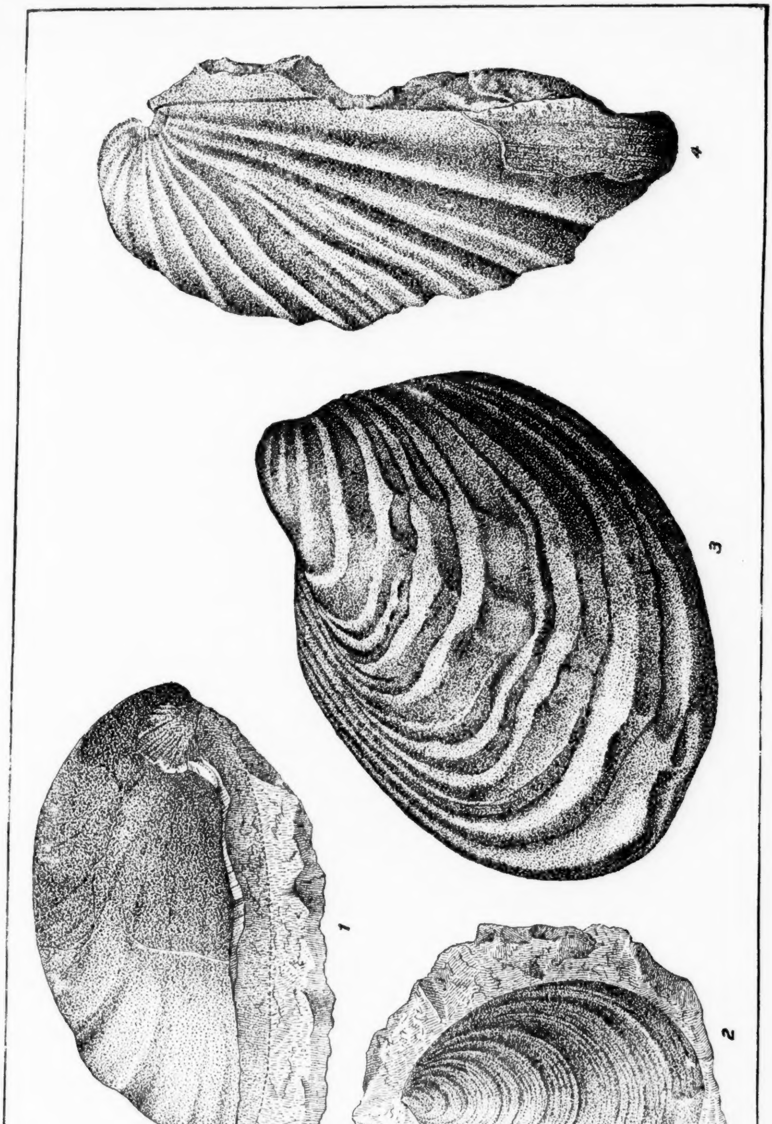
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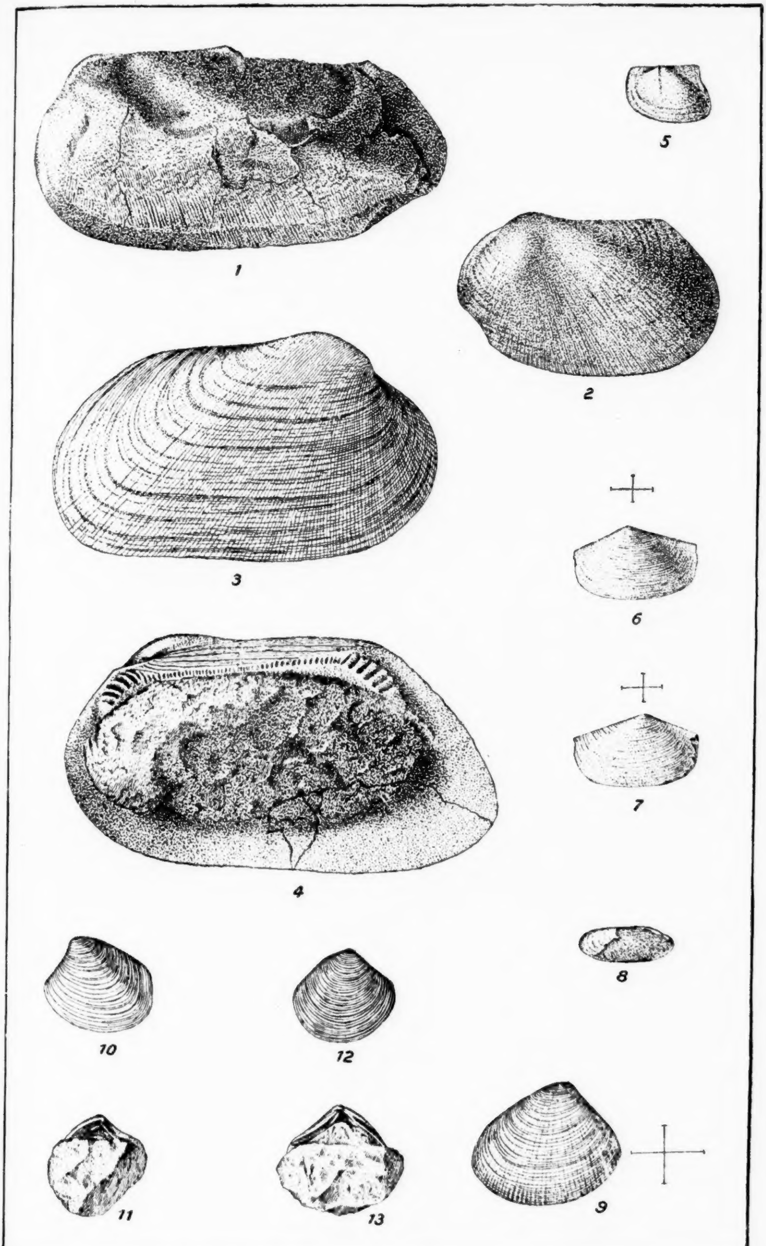
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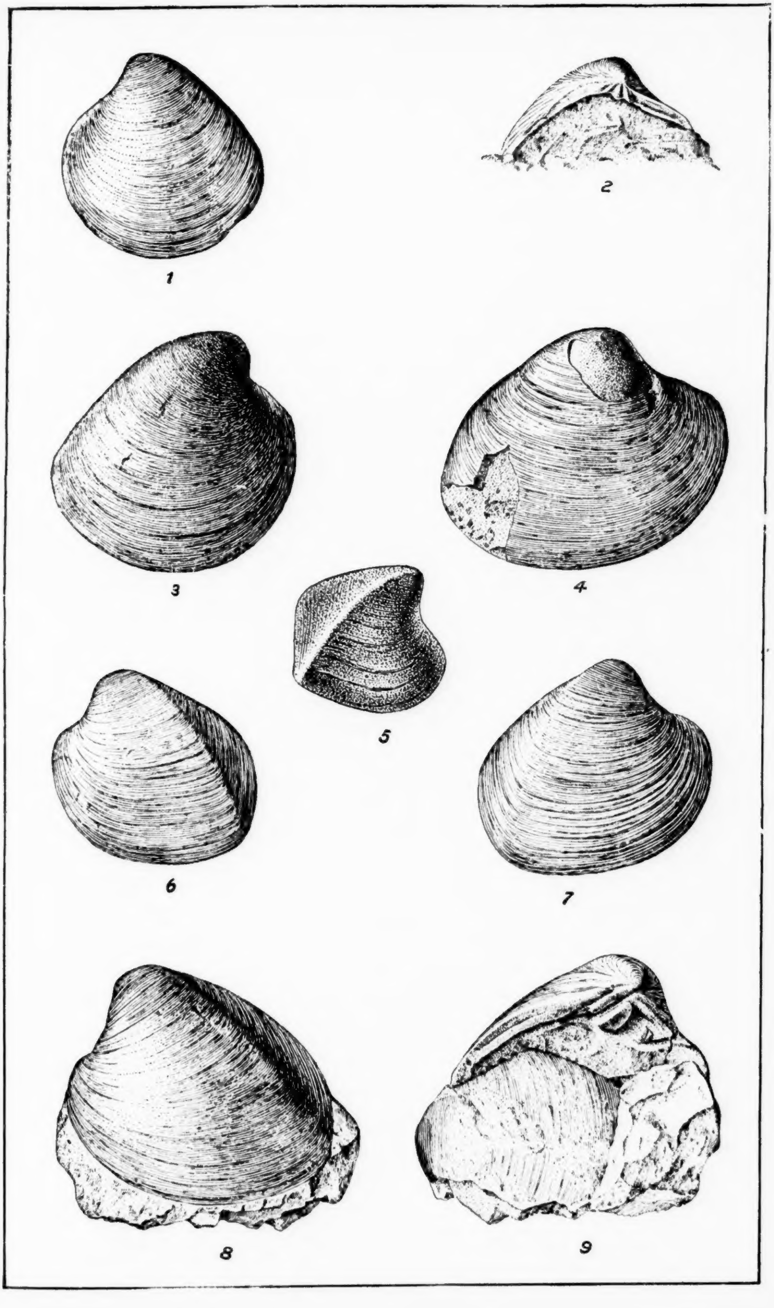
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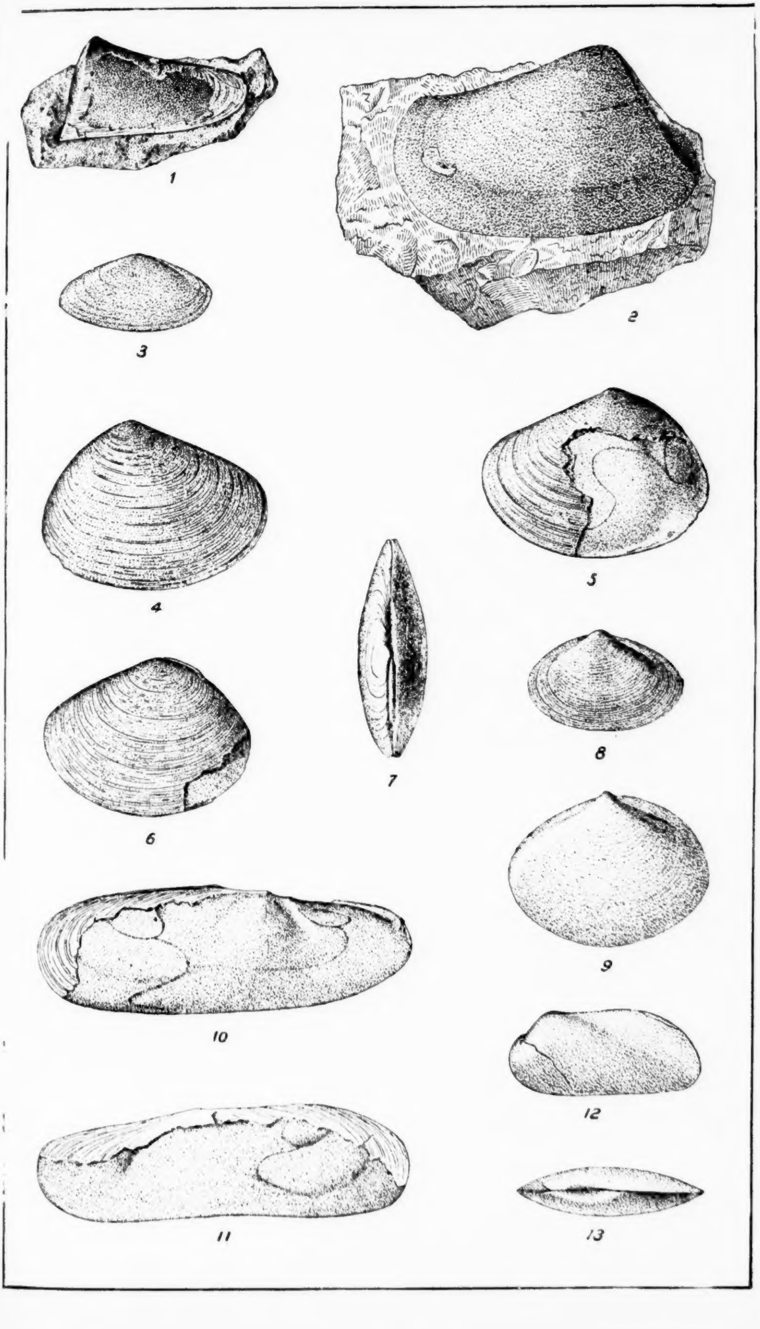
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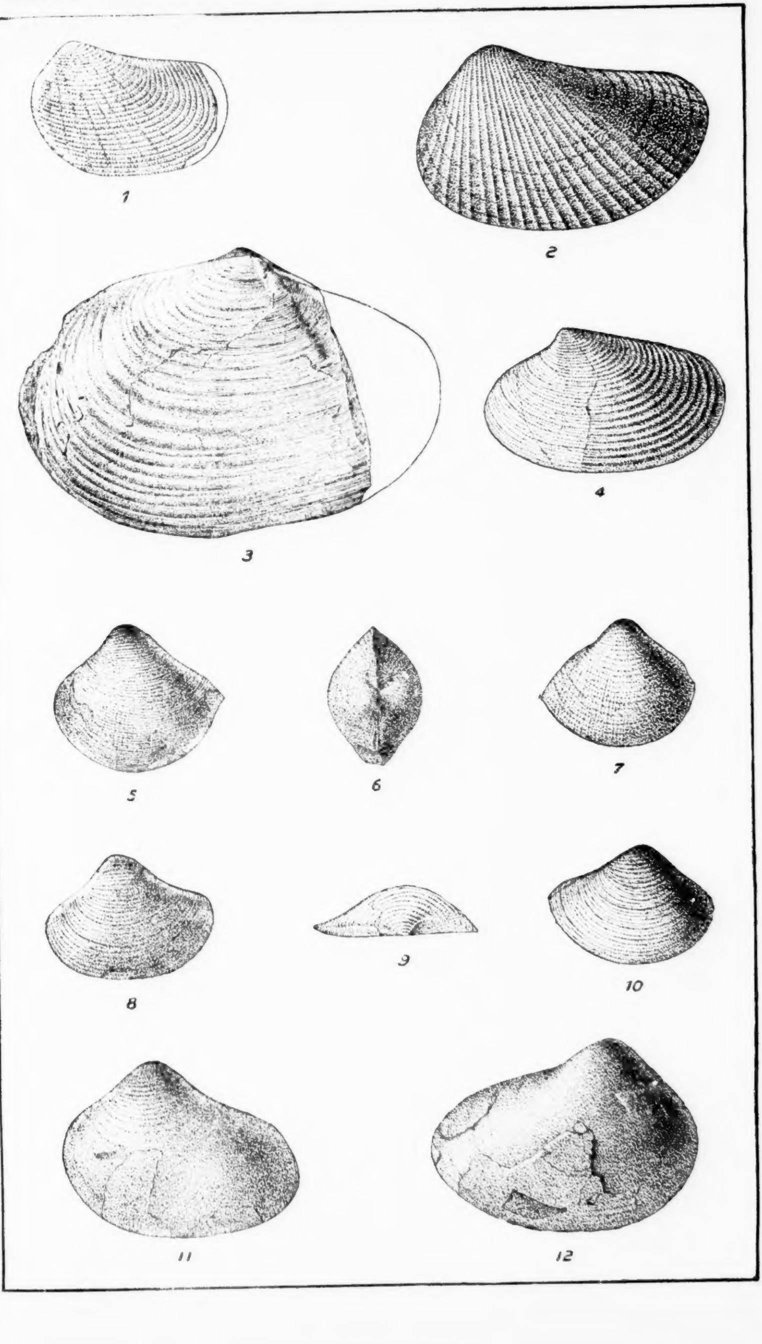
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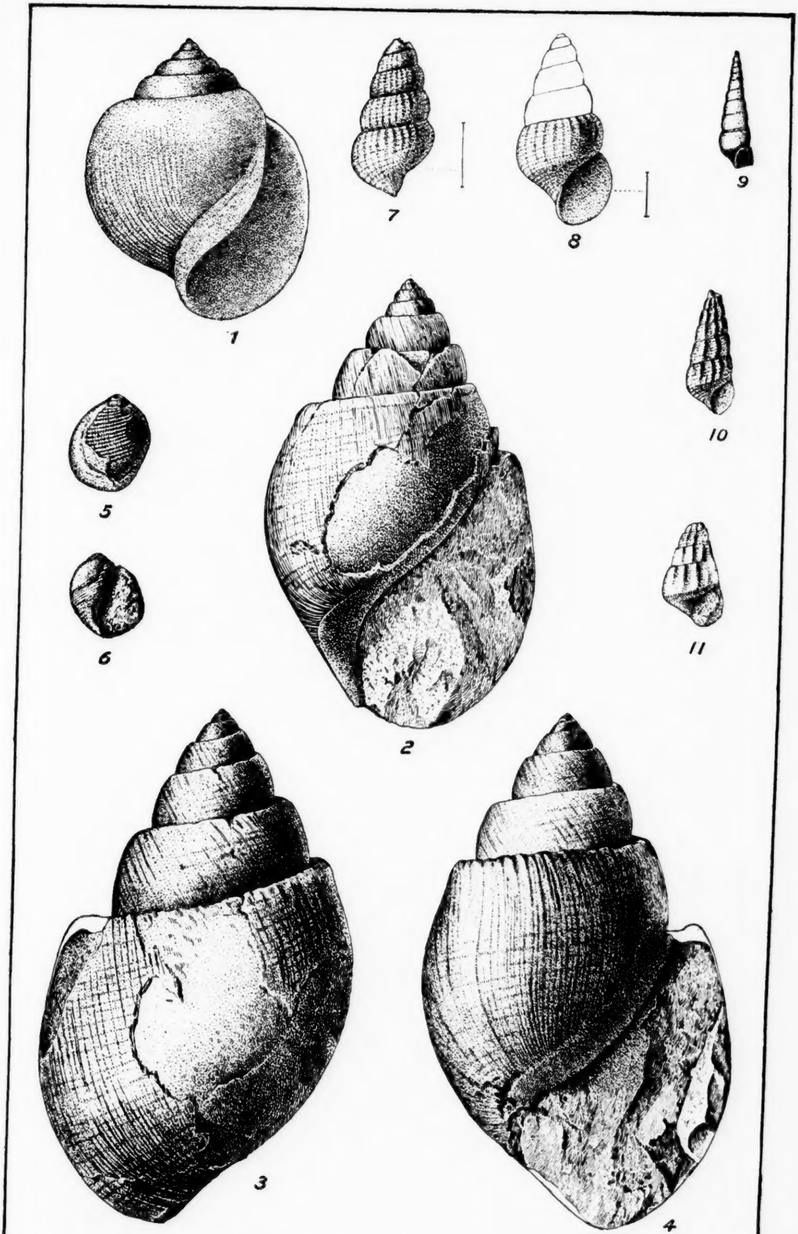
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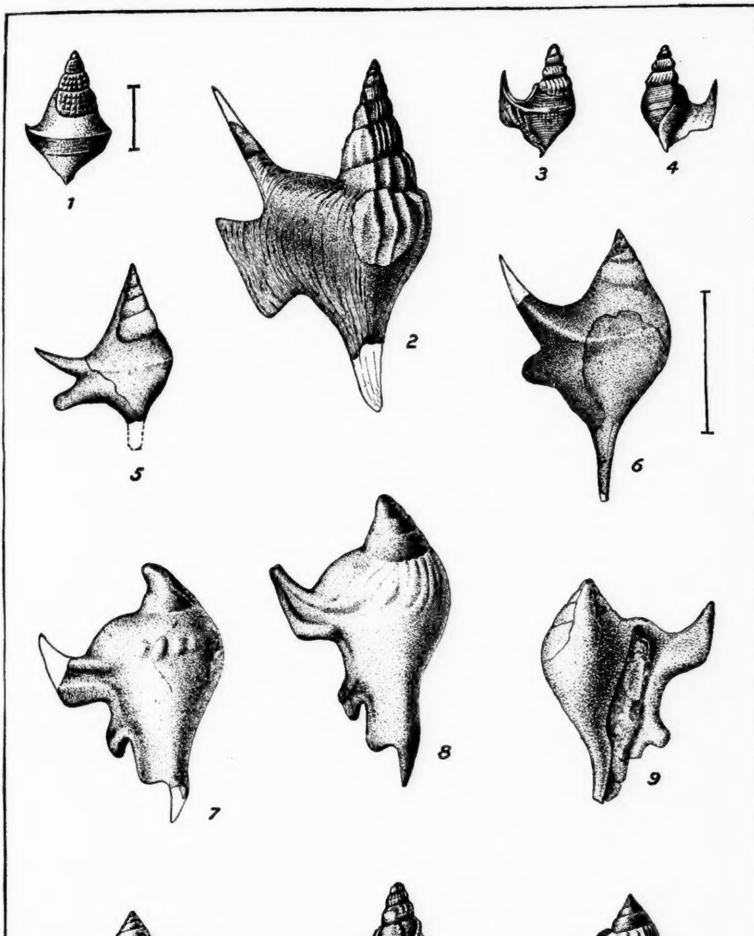
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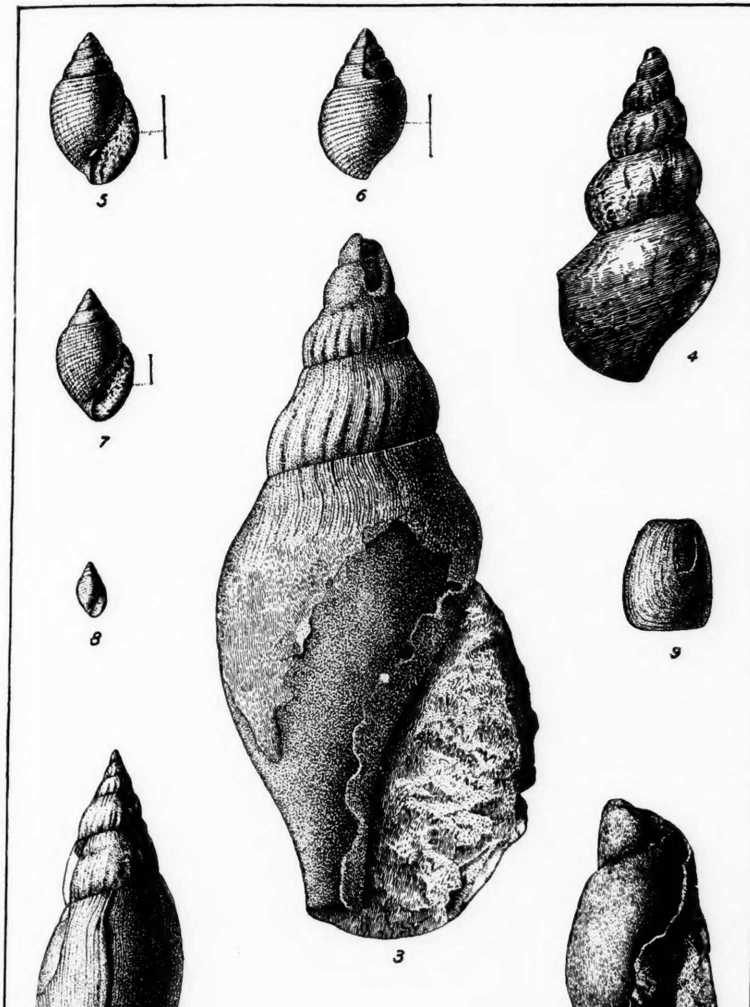
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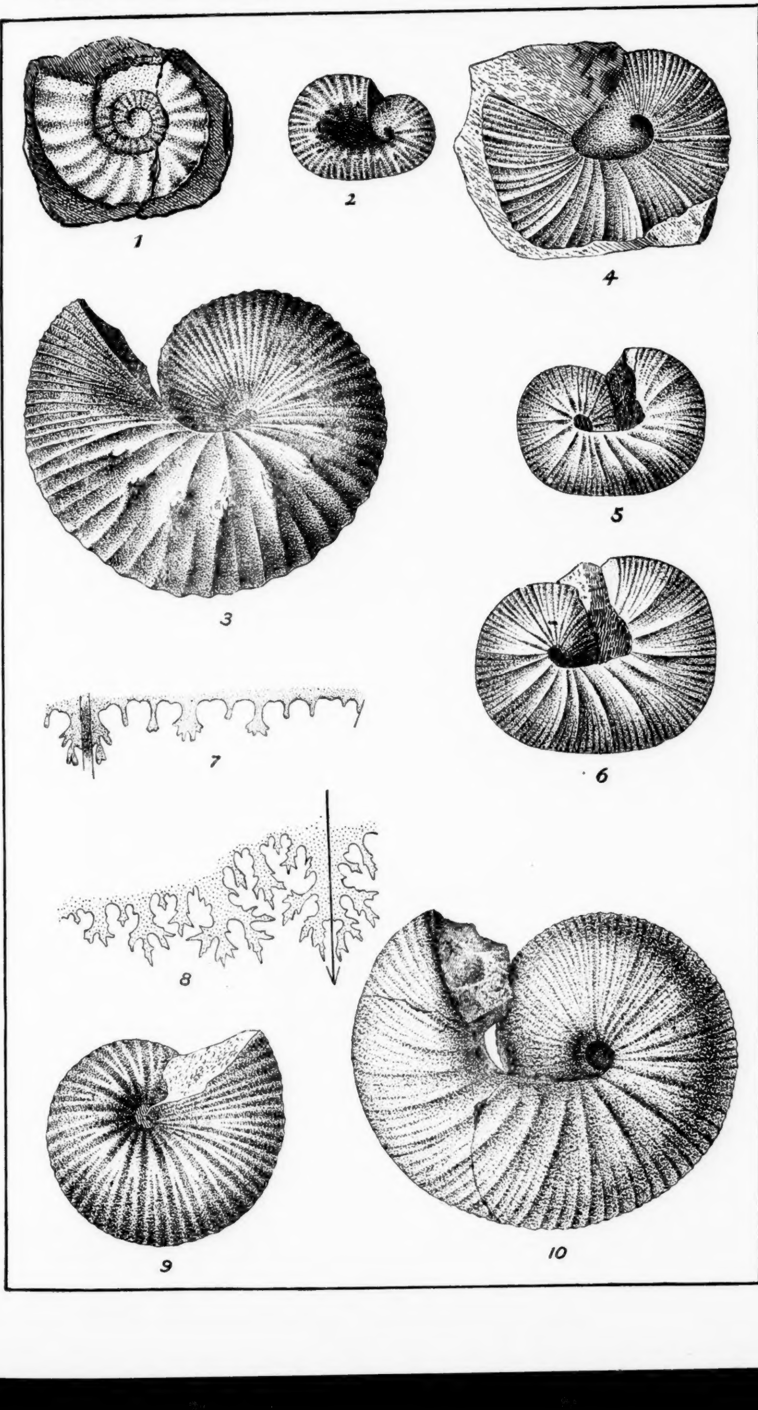
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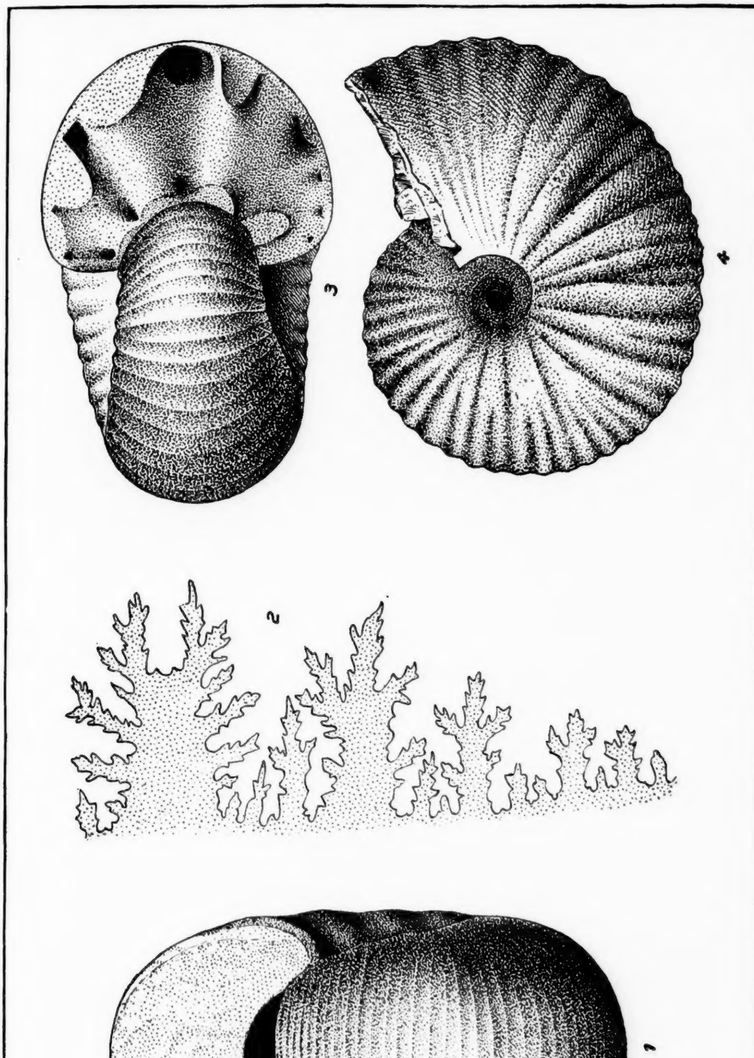
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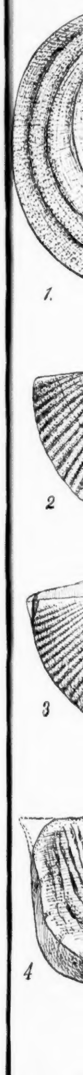

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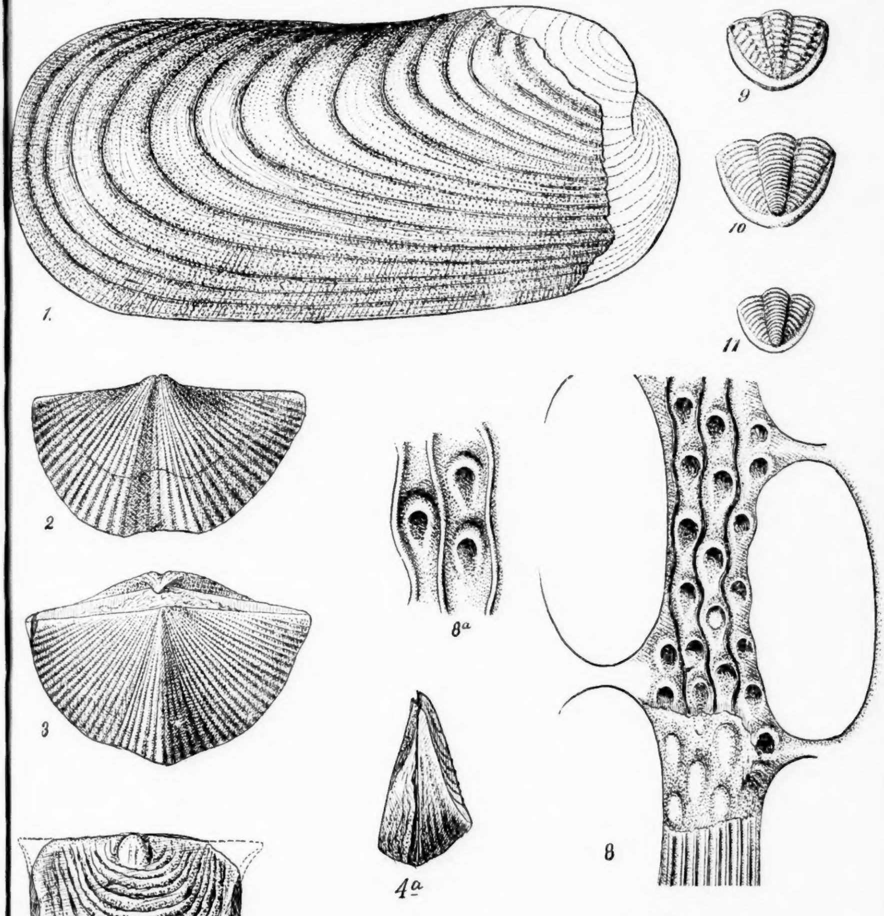
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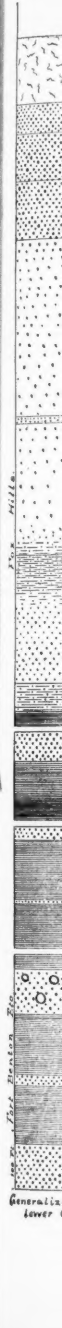

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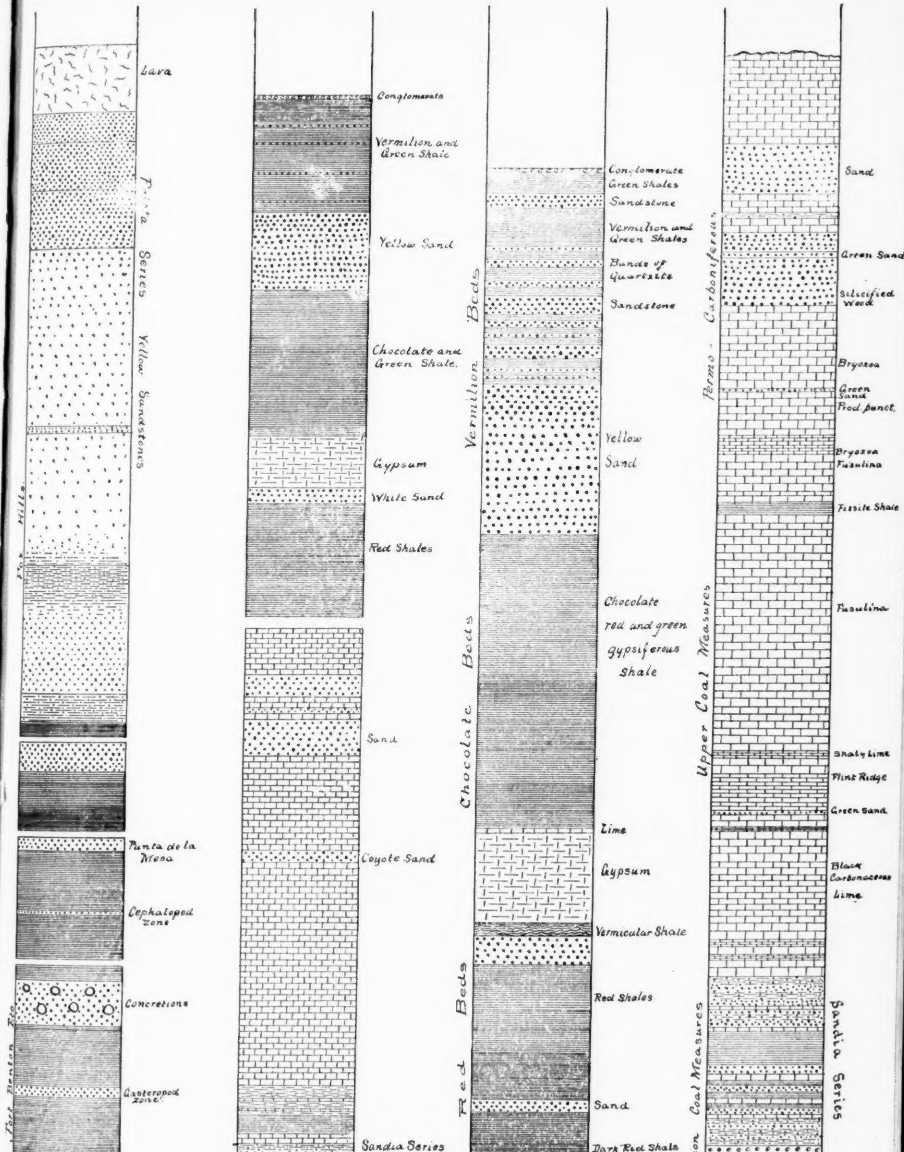
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Series
Yellow Sandstones
Fox Hills
Punta de la Mesa
Cephalopod zone
Concretions
Fort Benton Fm
Gasteropod zone
Conglomerate
Generalized Section Lower Cretaceous.
Conglomerate
Vermilion and Green Shale
Yellow Sand
Chocolate and Green Shale.
Gypsum
White Sand
Red Shales
Sand
Coyote Sand
Sandia Series
Basal Quartzite
Generalized Section Perm. and Carb.
Vermilion Beds
Conglomerate
Green Shales
Sandstone
Vermilion and Green Shales
Bands of Quartzite
Sandstone
Yellow Sand
Chocolate Beds
Chocolate red and green gypsiferous Shale
Lime
Gypsum
Vermicular Shale
Red Beds
Red Shales
Sand
Dark Red Shale
Red Series
Permo - Carboniferous
Sand
Green Sand
Silicified Wood
Bryozoa
Green Sand
Prod. punct.
Bryozoa
Fusulina
Fissile Shale
Fusulina
Upper Coal Measures
Shaly Lime
Flint Ridge
Green Sand
Black Carbonaceous Lime
Transition Coal Measures
Sandia Series
Basal Quartzite
Carboniferous.

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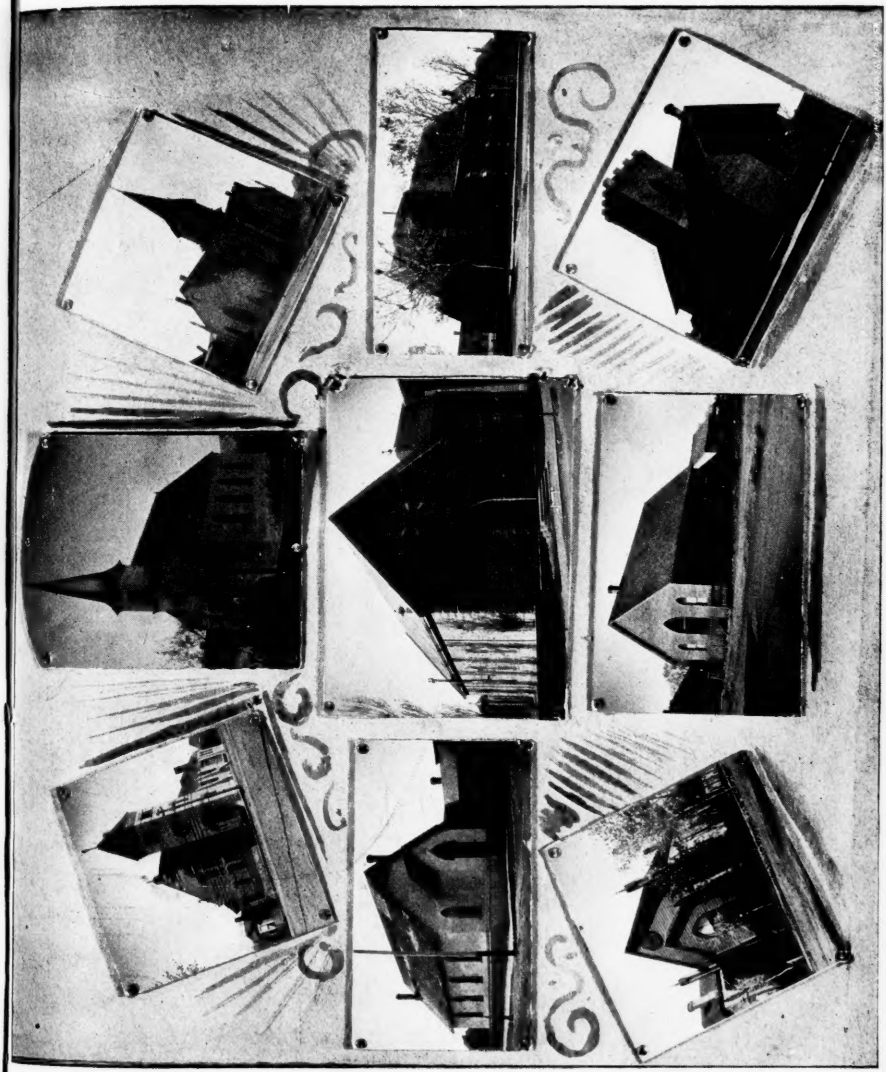
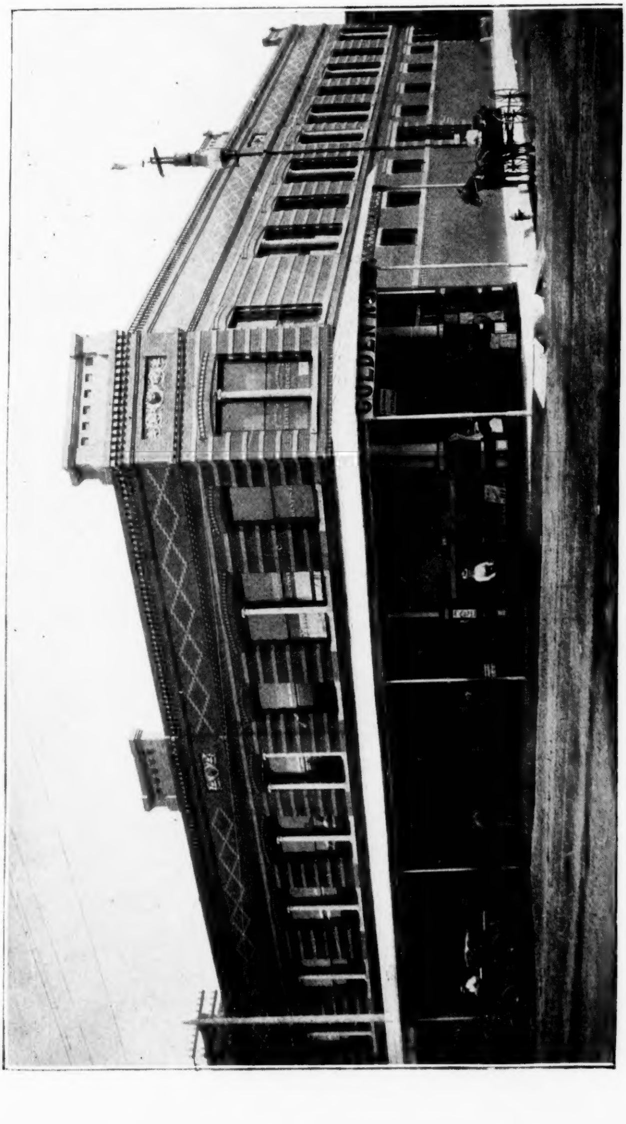


ALBUQUERQUE CHURCHES.

FIRST BAPTIST CHURCH.
LEAD AVENUE M. E. CHURCH.
HIGHLAND METHODIST CHURCH.
GERMAN LUTHERAN CHURCH.
IMMACULATE CONCEPTION CHURCH.
AFRICAN M. E. CHURCH.
CONGREGATIONAL CHURCH.
ST. JOHN'S EPISCOPAL CHURCH.
FIRST PRESBYTERIAN CHURCH.

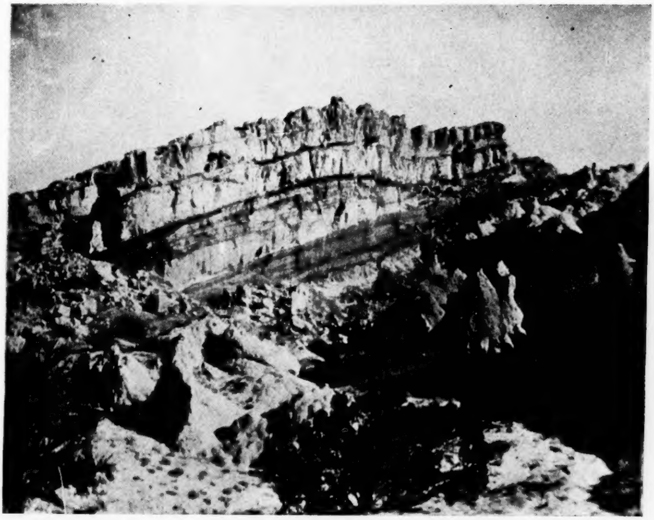


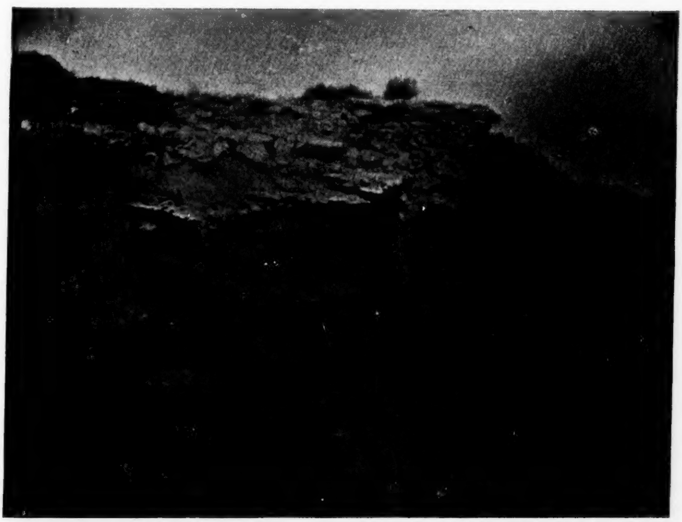
THE NEW GRANT BLOCK, CORNER RAILROAD AVENUE AND THIRD STREET.

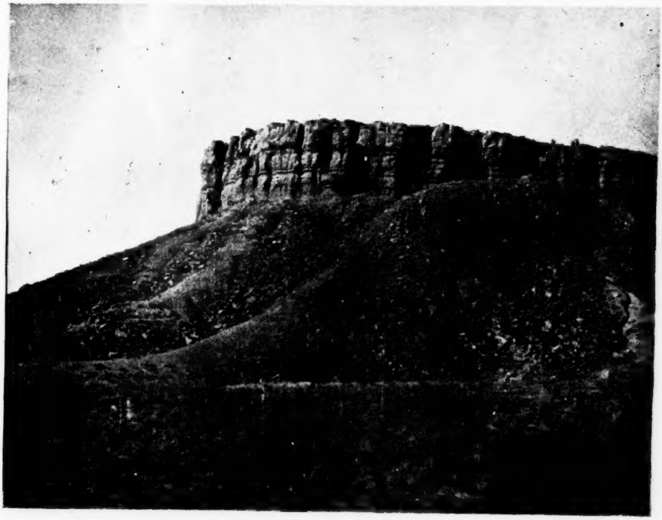
COMMERCIAL CLUB BUILDING, FOURTH STREET AND GOLD AVENUE.

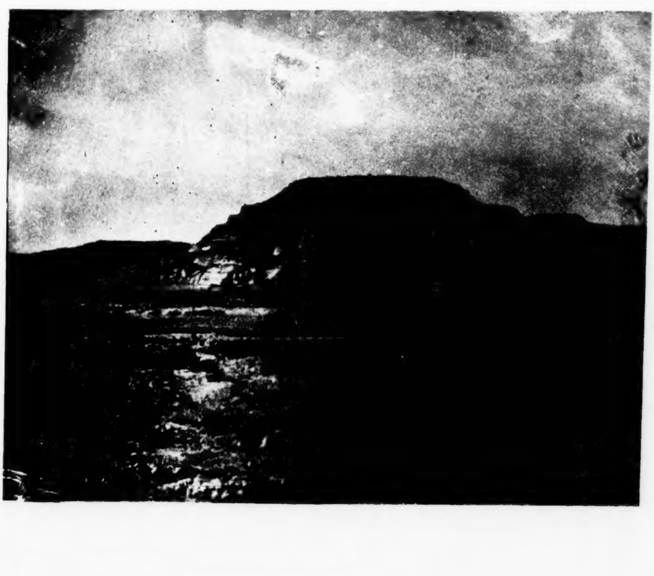
ALBUQUERQUE PUBLIC SCHOOL BUILDINGS.

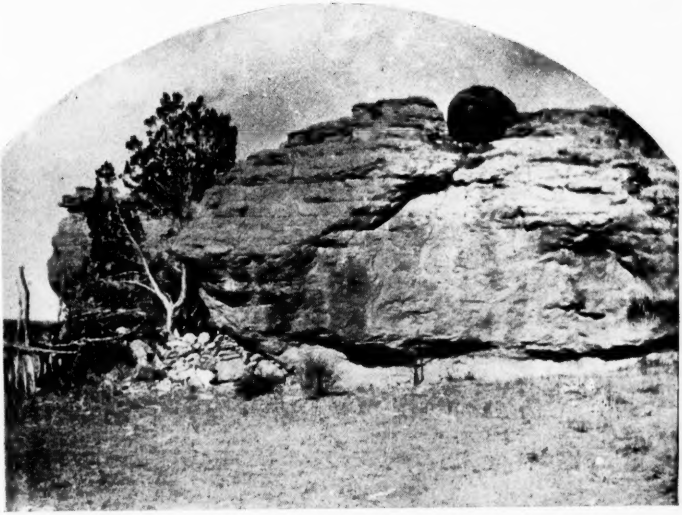
ALBUQUERQUE HOMES.

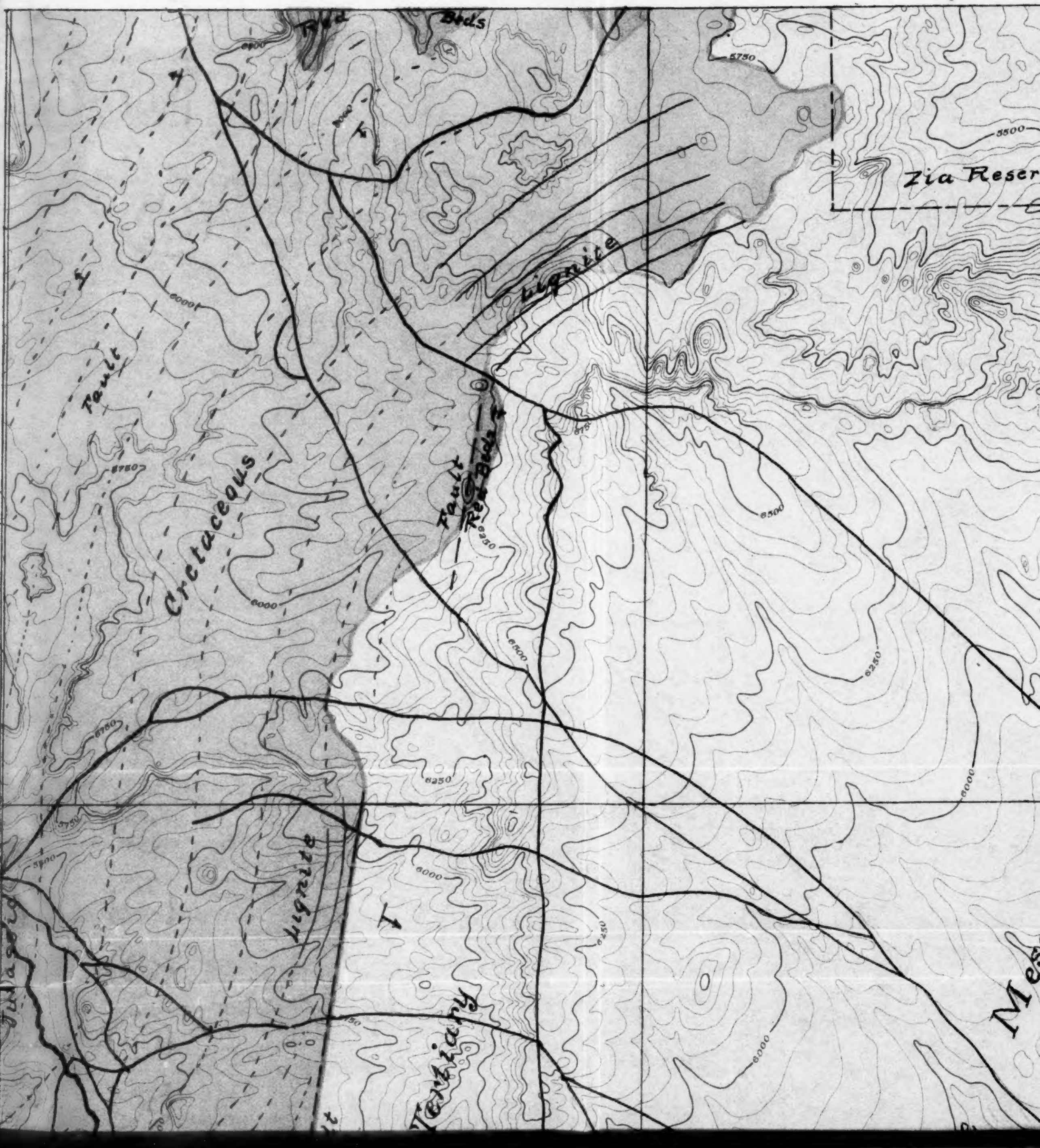












Red
Beds
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Lignite
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Cretaceous
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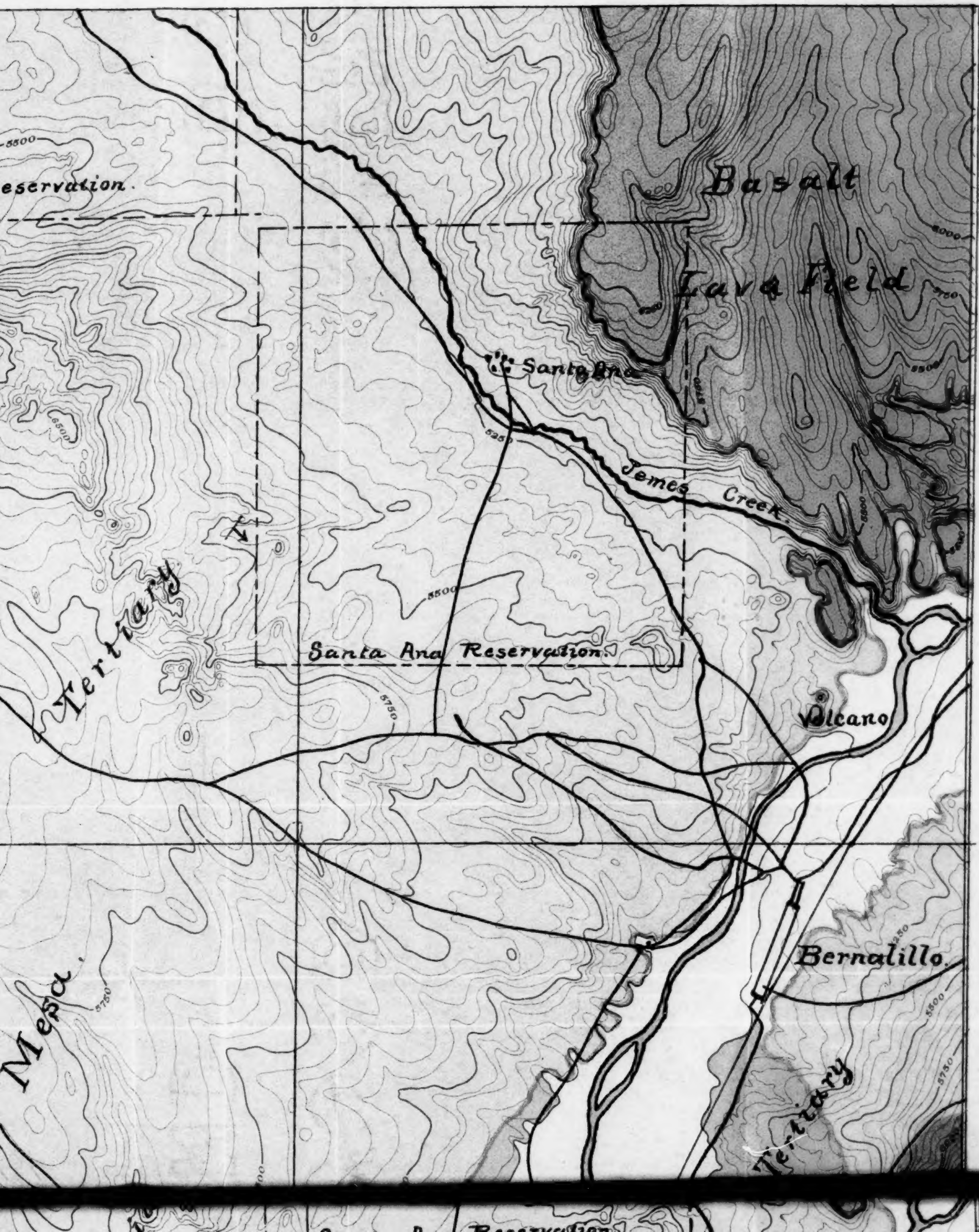
Lignite
Tertiary



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Basalt
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James Creek
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Tertiary
Volcano
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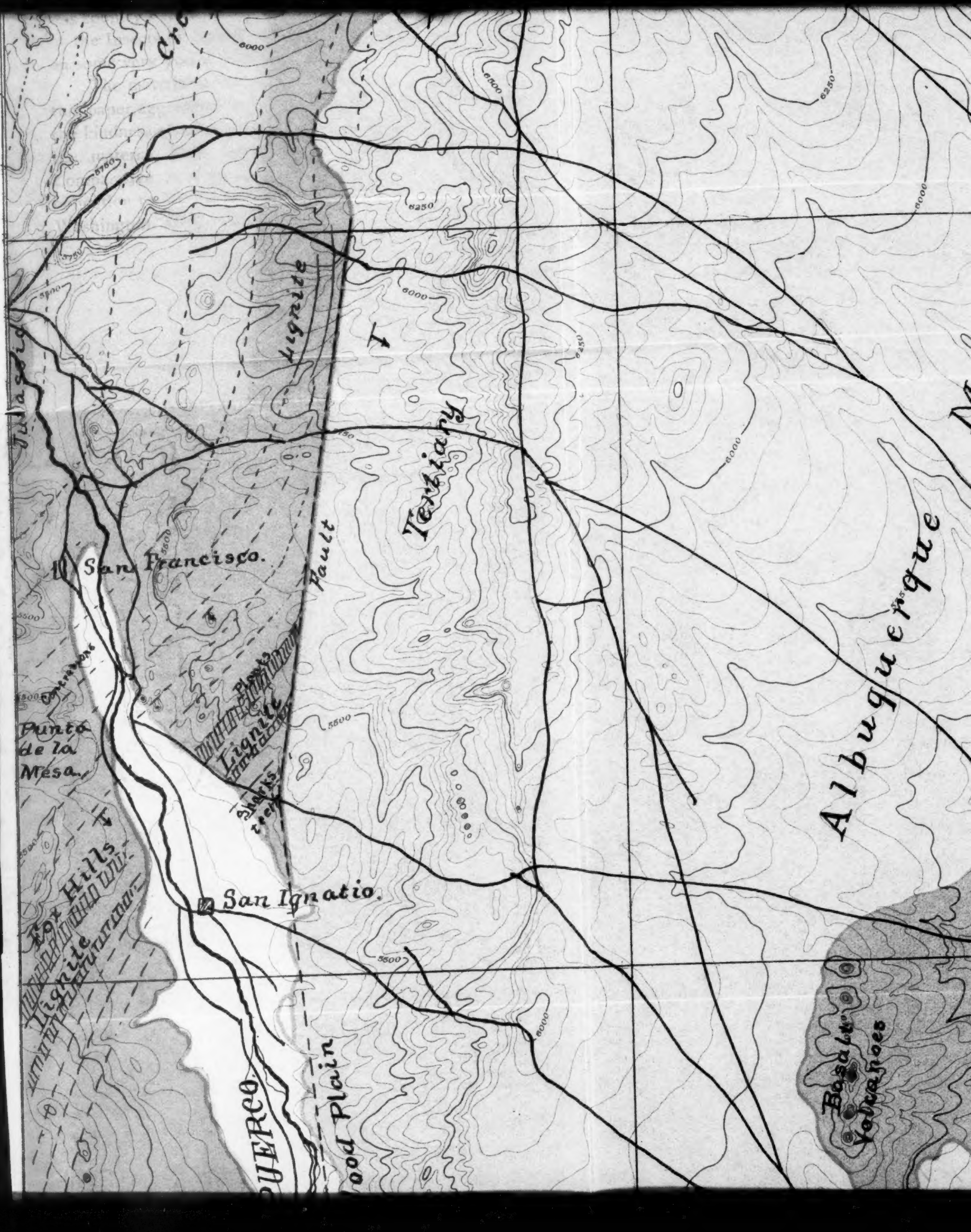
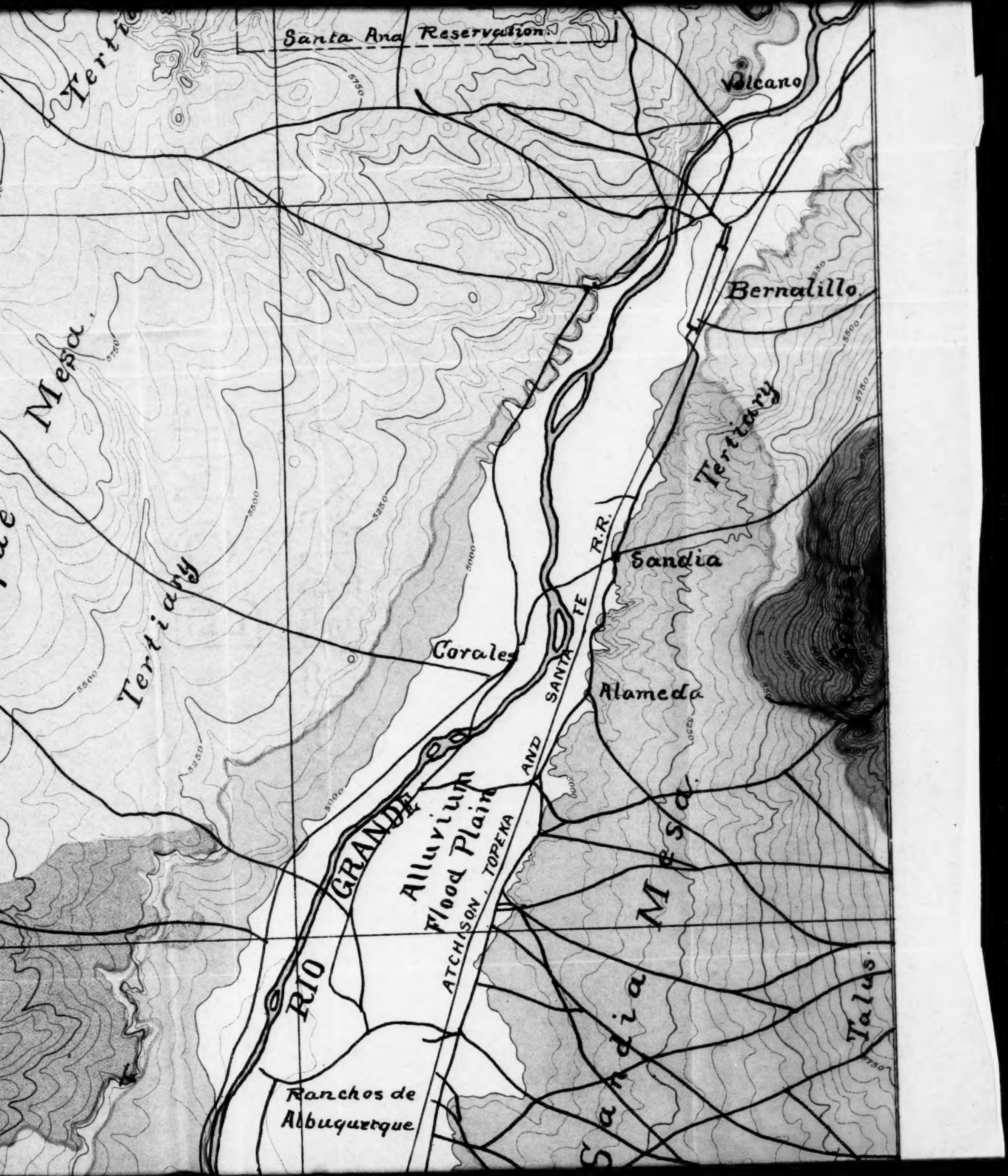
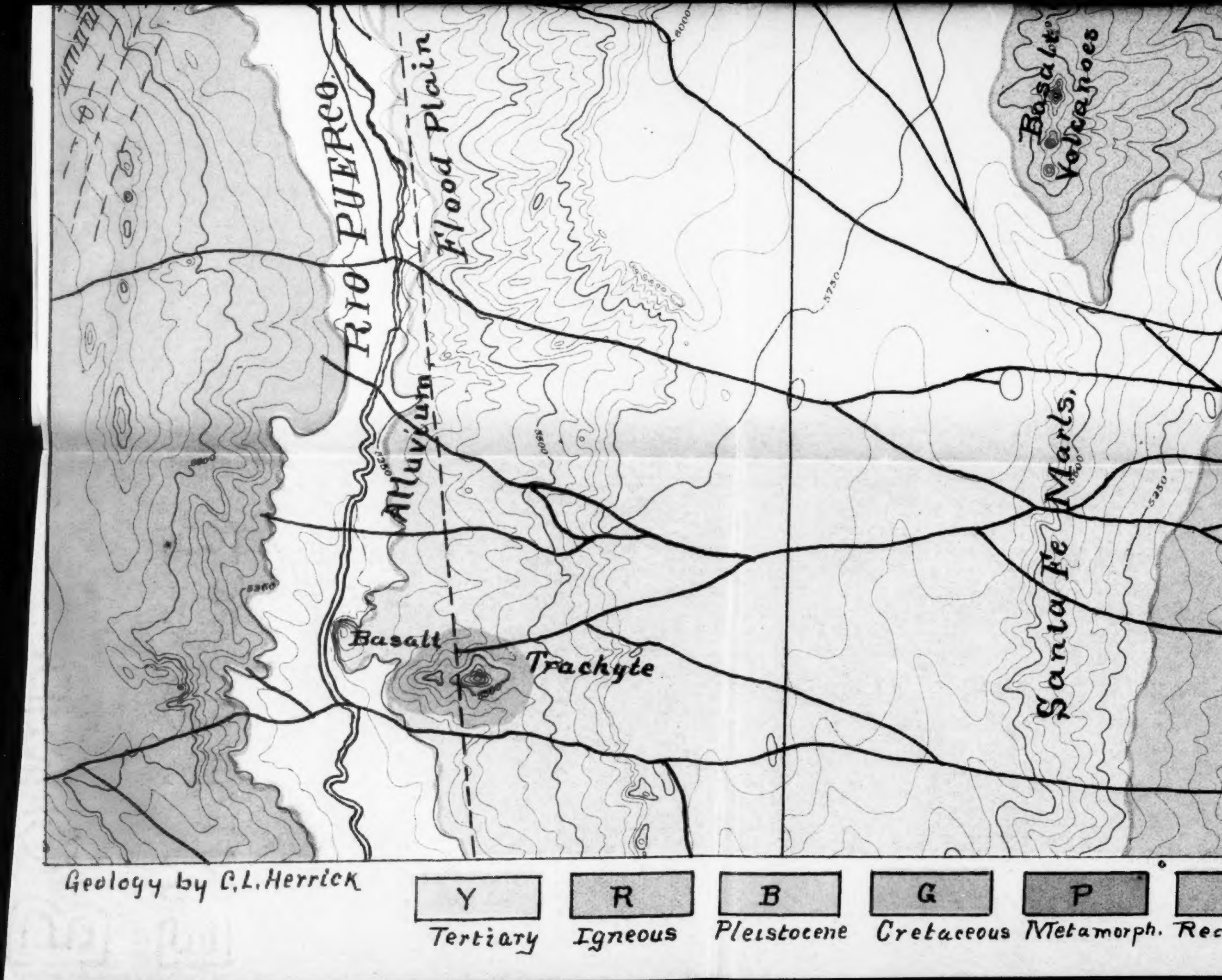
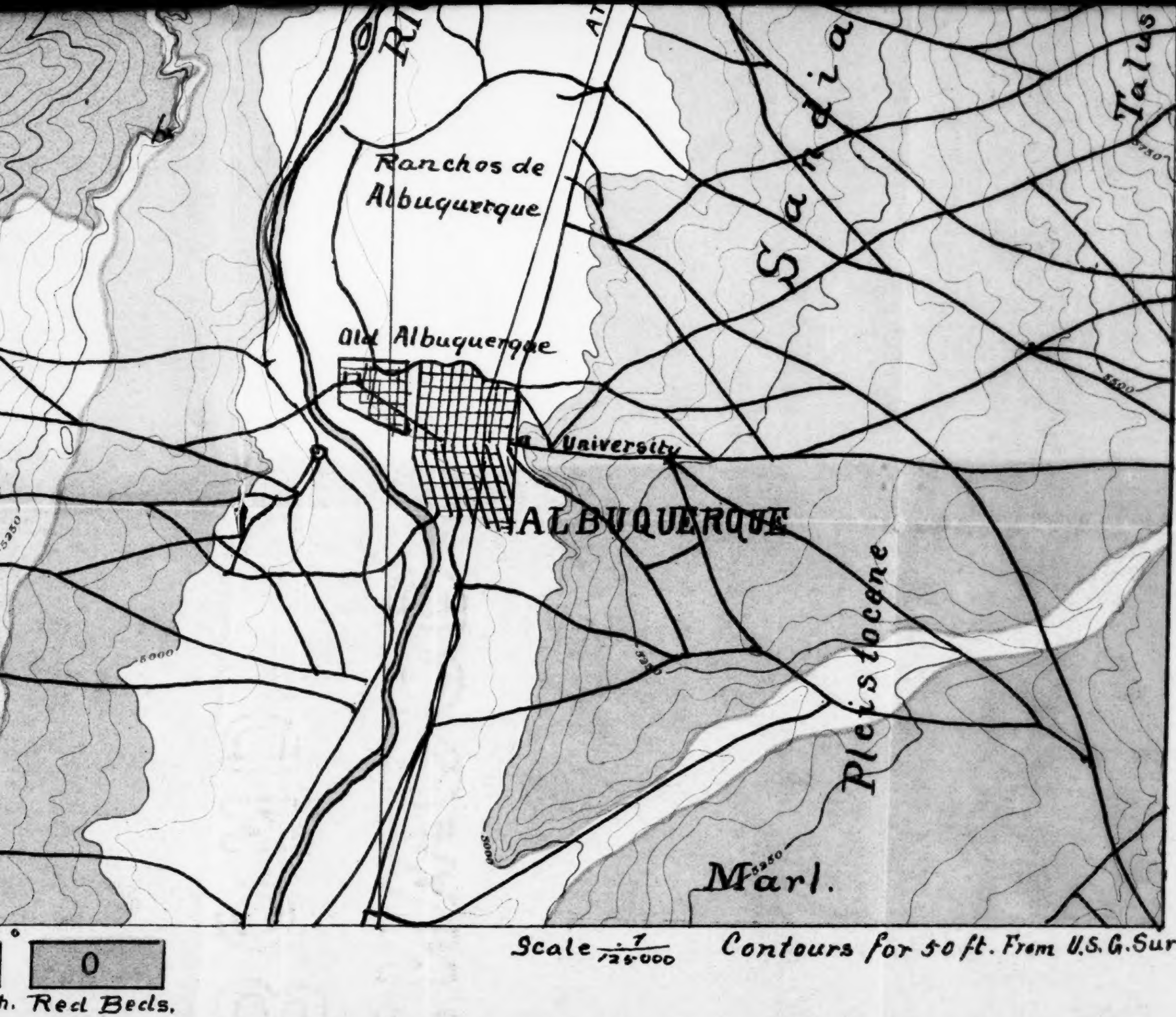
6000
6500


Lignite
T
Tertiary
Fault
San Francisco.
San Ignatio.
Punta de la Mesa.
Plants
Lignite
Sharks teeth
Fox Hills
Lignite
Albuquerque
Basalt Volcanoes
ood Plain
6000
6250
5500
5750



Santa Ana Reservation
Volcano
Bernalillo
Mesa
Tertiary
Tertiary
Tertiary
Sandia
Corales
Alameda
SANTA FE R.R.
ATCHISON, TOPEKA AND
RIO GRANDE
Alluvium
Flood Plain
Sandia Mesa
Talus
Ranchos de
Albuquerque
5750
5500
5250
5000


RIO PUERCO
Flood Plain
Alluvium
Basalt
Trachyte
Santa Fe Marls
Basalt Volcanoes
6000
5750
5250
Geology by C.L.Herrick
Y
Tertiary
R
Igneous
B
Pleistocene
G
Cretaceous
P
Metamorph.
Rec


Ranchos de Albuquerque
Old Albuquerque
University
ALBUQUERQUE
Sandia
Talus
Pleistocene
Marl.
0
h. Red Beds.
Scale $\frac{1}{125000}$
Contours for 50 ft. From U.S.G.Sur.